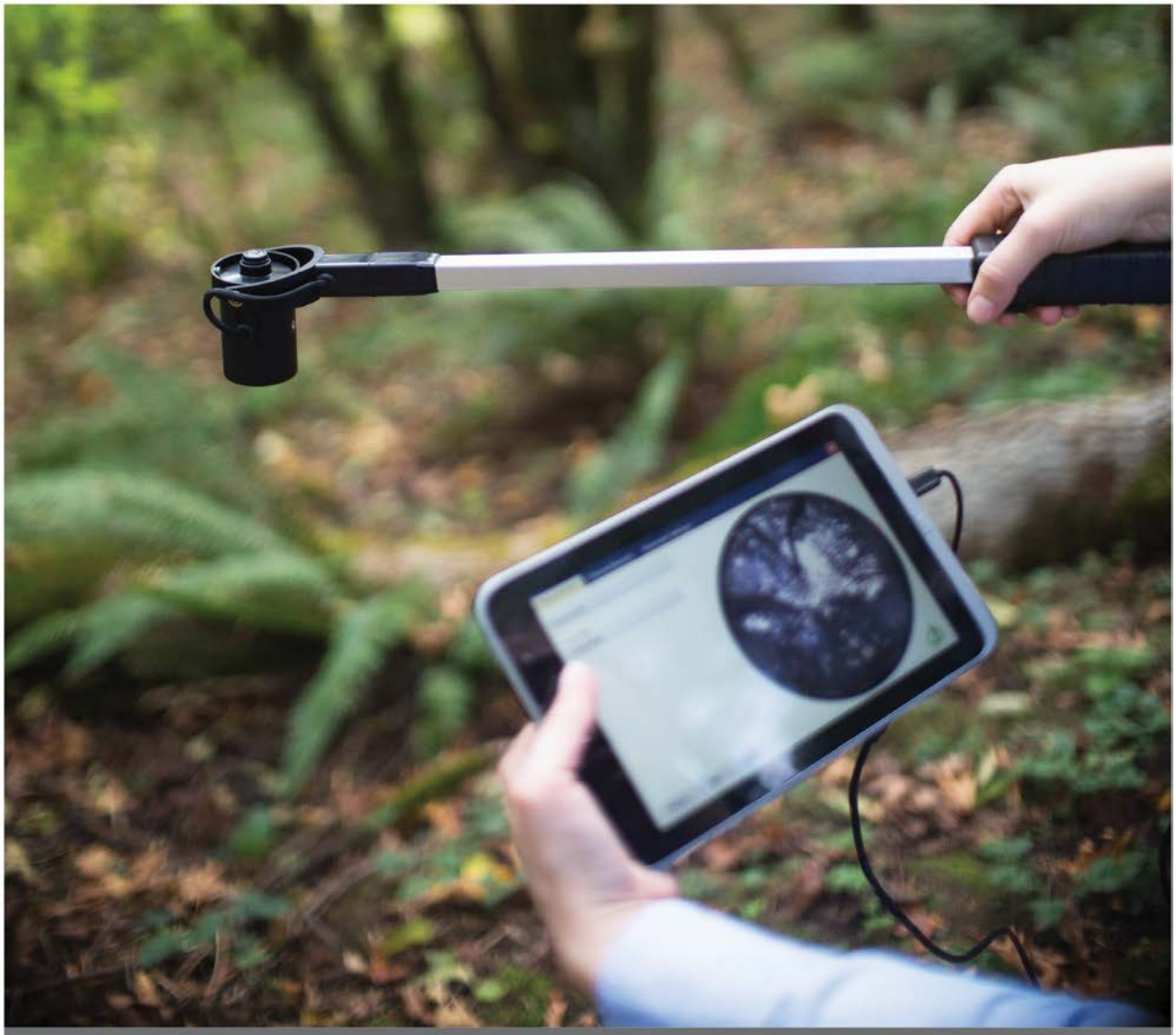
CID Bio-Science INC.
Tools that work where you work.



OPERATIONS MANUAL

CI-110 Plant Canopy Imager

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CI-110 Plant Canopy Imager

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Manual available online at
https://cid-felix.gitbooks.io/ci-110-operation-manual/content/

> Revised 02/22/18

CI-110 Plant Canopy Imager

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.

Specifications

Imager Specifications	
Lens	Self-leveling hemispherical lens
Image Resolution	768x494
Interface	USB
Measuring Time	0.5-1 sec
Fish-Eye Lens Angle	150
Operating Temperature	5-50°C
Probe Size	20x20 mm
Arm Length	440 mm
Probe and Arm Weight	500 g

There are 24 PAR sensors on the CI-110, located along the top of the arm spaced 10 mm apart. The PAR sensors are filtered GaAsP (gallium arsenide phosphide) photodiodes. The specifications are in the following table.

Par Sensor Specifications	
Range	0-2500 µmol/m2 s
Accuracy	5 µmol/m2 s
Response	400 - 700 nm

Software Installation

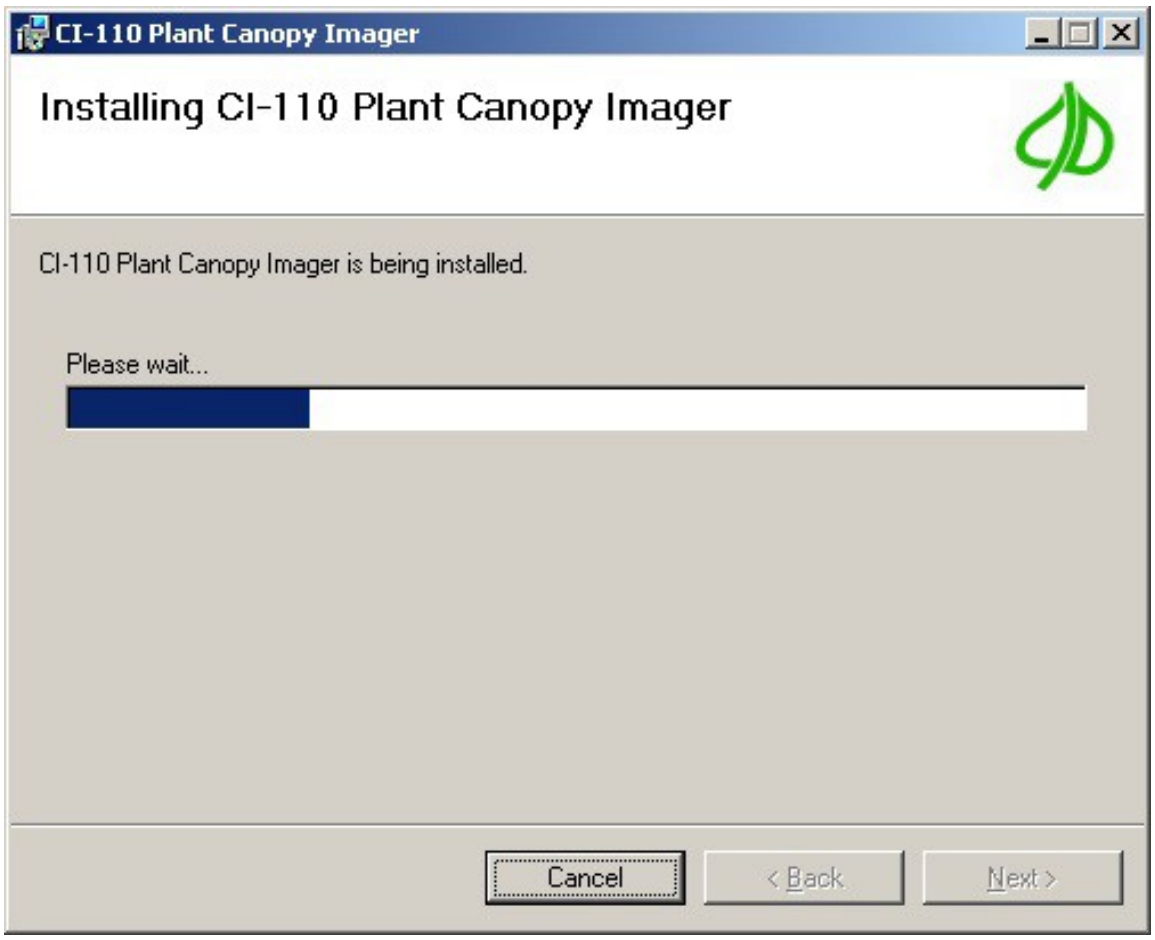
The CI-110 software arrives pre-installed on a tablet computer. The CI-110 software can be installed on another computer, either for field use or to analyze images later, and the following steps should be repeated on each computer used with the CI-110 Plant Canopy Imager.

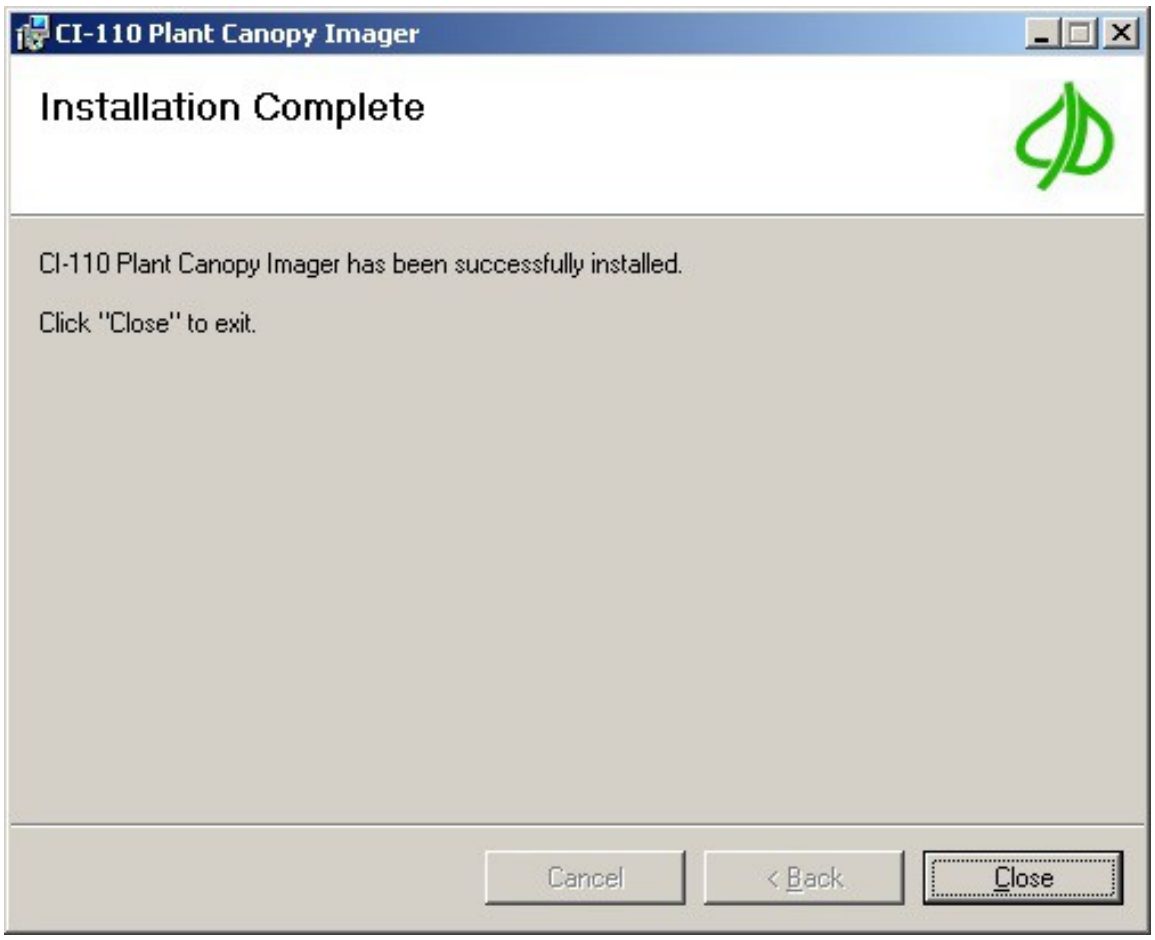
To check for updates on software, navigate to the software support link below, or within the Plant Canopy Analysis Software under Advanced Settings > Check for Updates (internet connection required).

The instructions for installing CI-110 Plant Canopy Analysis Software version 6.0 are the same for Windows 7, 8 and 10. The current version of CI-110 software can be downloaded from the web at: https://www.cid-inc.com/support/CI-110/software/

Navigate to the webpage and select the download for the “current version” of software or software version compatible to your unit serial number. Run the .exe file to install the software. Follow the prompts to download and install the software on

your PC.


CI-110 Plant Canopy Imager
Installing CI-110 Plant Canopy Imager
CI-110 Plant Canopy Imager is being installed.
Please wait...
Cancel
< Back
Next >


CI-110 Plant Canopy Imager
Installation Complete
CI-110 Plant Canopy Imager has been successfully installed.
Click "Close" to exit.
Cancel
< Back
Close

Hardware Installation

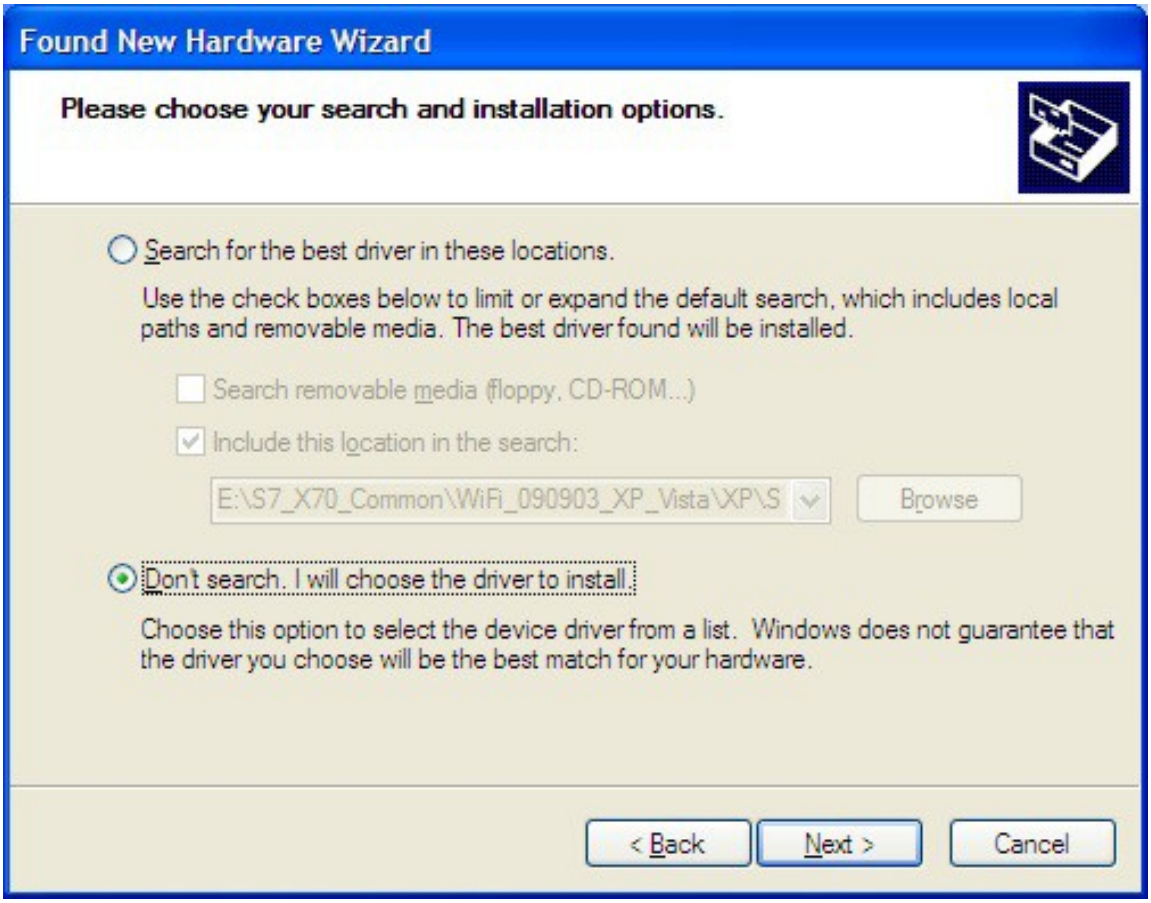
The CI-110 is supplied with the hardware and driver installed on a tablet computer. The following steps should be repeated on each computer used with the CI-110 Plant Canopy Imager. The driver is compatible with 32 and 64 bit operating systems.

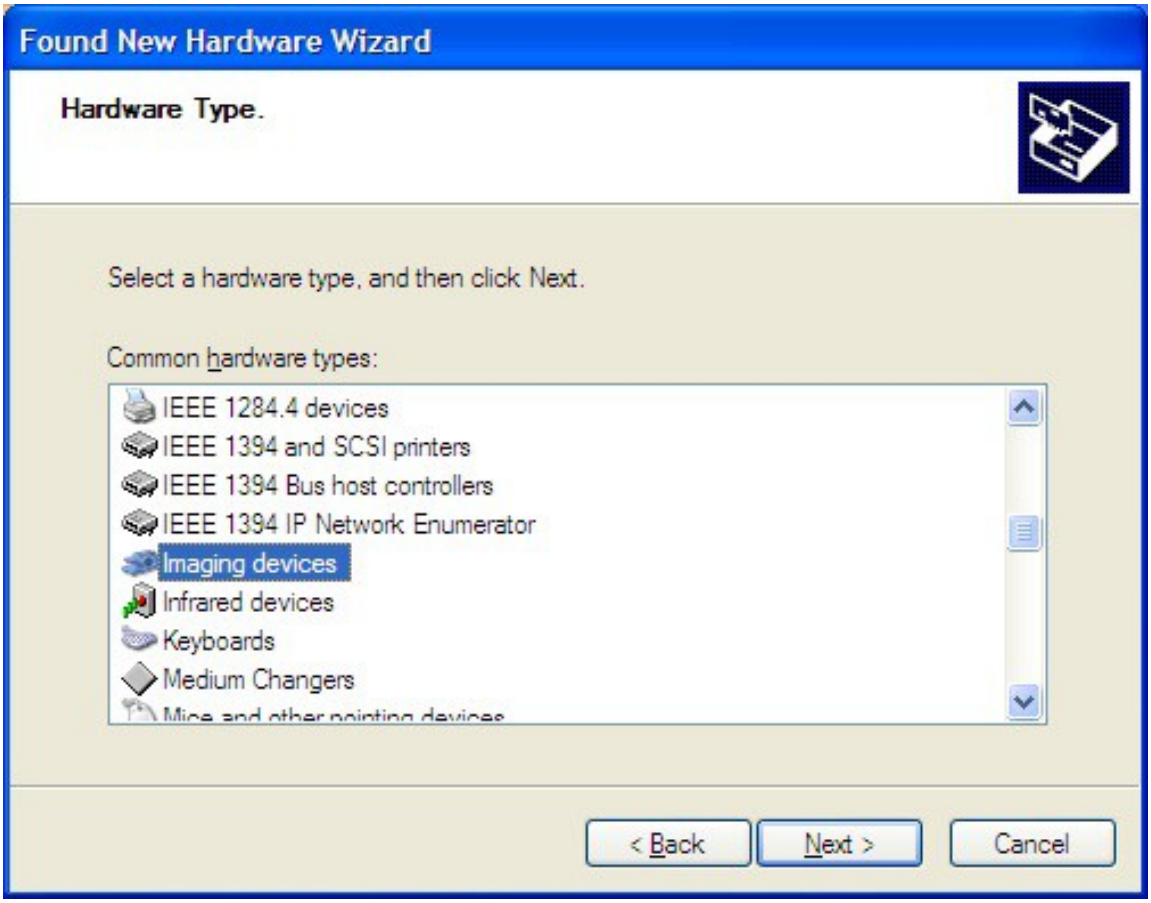
The driver is installed through the CI-110 Plant Canopy Analysis software. To install the driver after downloading the software:

1. Connect the CI-110 to the PC's USB port.
2. Open the CI-110 software.
3. Select the *Advanced Settings Tab*.
4. Select ***Install Driver***.
5. Click ***Next*** in the Device Driver Installation Wizard.
6. Click ***Finish*** to complete the driver installation.

Found New Hardware Wizard
Welcome to the Found New Hardware Wizard
Windows will search for current and updated software by looking on your computer, on the hardware installation CD, or on the Windows Update Web site (with your permission).
Read our privacy policy
Can Windows connect to Windows Update to search for software?
Yes, this time only
Yes, now and every time I connect a device
No, not this time
Click Next to continue.
< Back
Next >
Cancel

Found New Hardware Wizard
Welcome to the Found New Hardware Wizard
This wizard helps you install software for:
USB2.0 PC Camera
If your hardware came with an installation CD or floppy disk, insert it now.
What do you want the wizard to do?
Install the software automatically (Recommended)
Install from a list or specific location (Advanced)
Click Next to continue.
< Back
Next >
Cancel

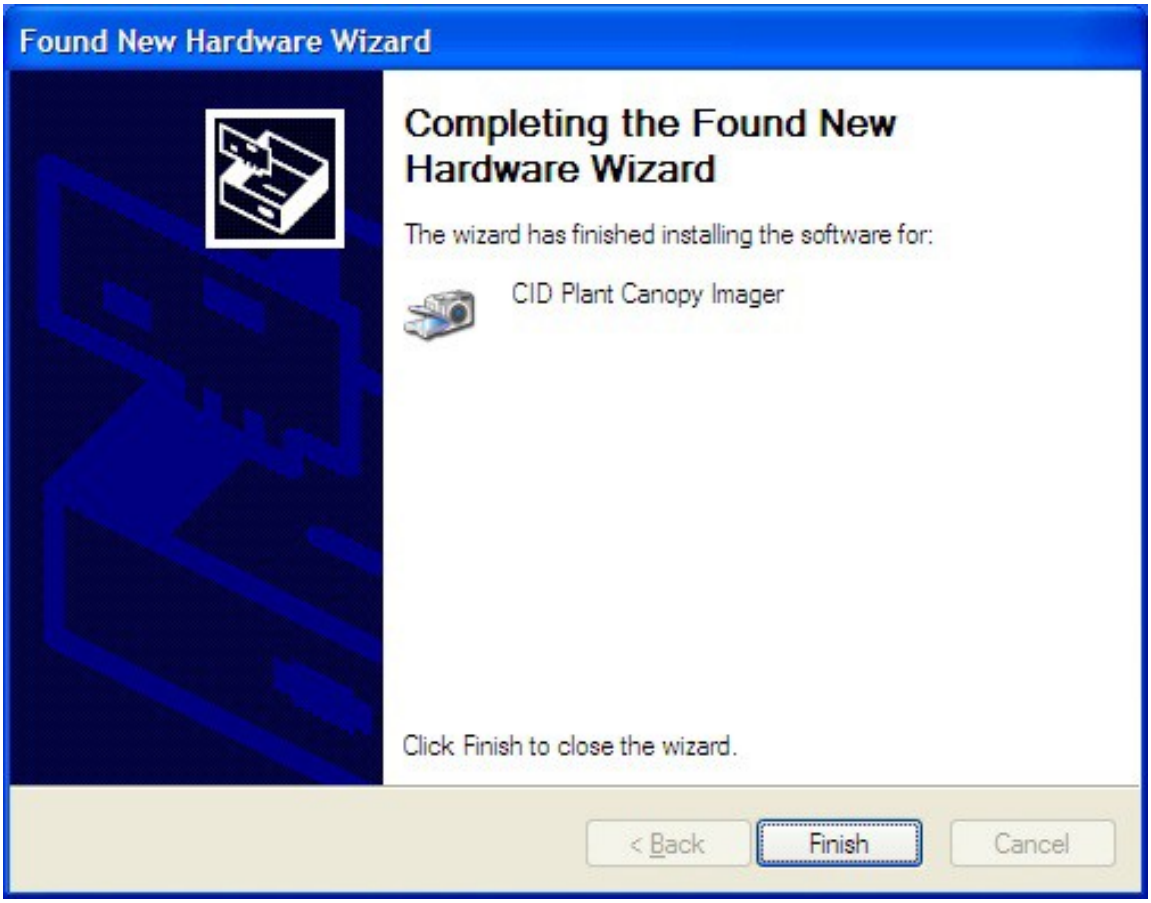

Found New Hardware Wizard
Please choose your search and installation options.
Search for the best driver in these locations.
Use the check boxes below to limit or expand the default search, which includes local paths and removable media. The best driver found will be installed.
Search removable media (floppy, CD-ROM...)
Include this location in the search:
E:\S7_X70_Common\WiFi_090903_XP_Vista\XP\S
Browse
Don't search. I will choose the driver to install.
Choose this option to select the device driver from a list. Windows does not guarantee that the driver you choose will be the best match for your hardware.
< Back
Next >
Cancel


Found New Hardware Wizard
Hardware Type.
Select a hardware type, and then click Next.
Common hardware types:
IEEE 1284.4 devices
IEEE 1394 and SCSI printers
IEEE 1394 Bus host controllers
IEEE 1394 IP Network Enumerator
Imaging devices
Infrared devices
Keyboards
Medium Changers
< Back
Next >
Cancel

Found New Hardware Wizard
Select the device driver you want to install for this hardware.
Select the manufacturer and model of your hardware device and then click Next. If you have a disk that contains the driver you want to install, click Have Disk.
(Unable to find any drivers for this device)
Have Disk...
< Back
Next >
Cancel

Found New Hardware Wizard
Select the device driver you want to install for this hardware.
Select the manufacturer and model of your hardware device and then click Next. If you have a disk that contains the driver you want to install, click Have Disk.
(Unable to find any drivers for this device)
Have Disk...
< Back
Next >
Cancel

Hardware Installation
The software you are installing for this hardware:
CID Plant Canopy Imager
has not passed Windows Logo testing to verify its compatibility with Windows XP. (Tell me why this testing is important.)
Continuing your installation of this software may impair or destabilize the correct operation of your system either immediately or in the future. Microsoft strongly recommends that you stop this installation now and contact the hardware vendor for software that has passed Windows Logo testing.
Continue Anyway
STOP Installation


Found New Hardware Wizard
Completing the Found New Hardware Wizard
The wizard has finished installing the software for:
CID Plant Canopy Imager
Click Finish to close the wizard.
< Back
Finish
Cancel

Application Functionality

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

Measurement

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 postmeasurement analysis.

Browse Records

Search, export, delete, edit and review saved records.

Advanced Settings

Configures the application and allows access to calibrate the device.

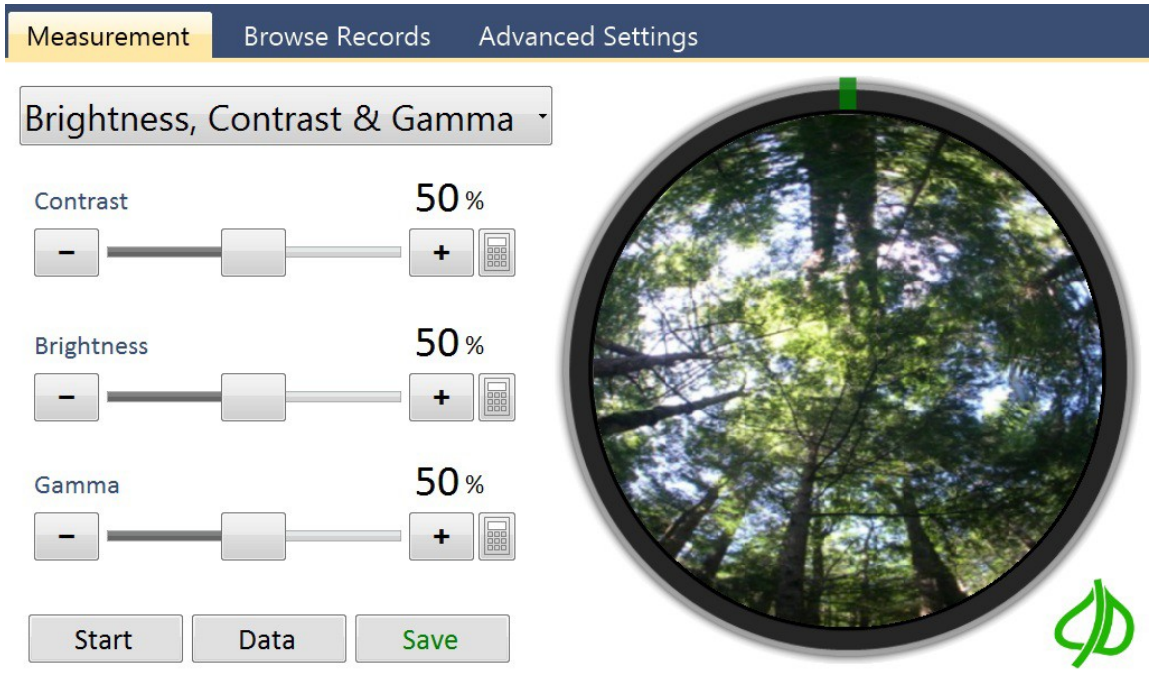
Getting Started

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 CI-110 software icon to open the software.
    - Or, click the Windows ***Start*** button and go to ***Programs*** and find the *CID-Bio Science* folder.
    - Select ***CI-110 Plant Canopy Imager***.

2. The dialog box 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 GPS 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 camera to the arm using the two ***top*** buttons for proper alignment.
2. Attach the CI-110 hardware via USB to the computer.
3. Open the Plant Canopy Analysis System software. The Start, Data and Save buttons will be enabled once the device is detected.

4. 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.

5. 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).

6. Click the ***Pause*** button to preview your measurement. Adjust the Brightness, Contrast & Gamma, etc. as

needed to increase the contrast between sky and foliage.

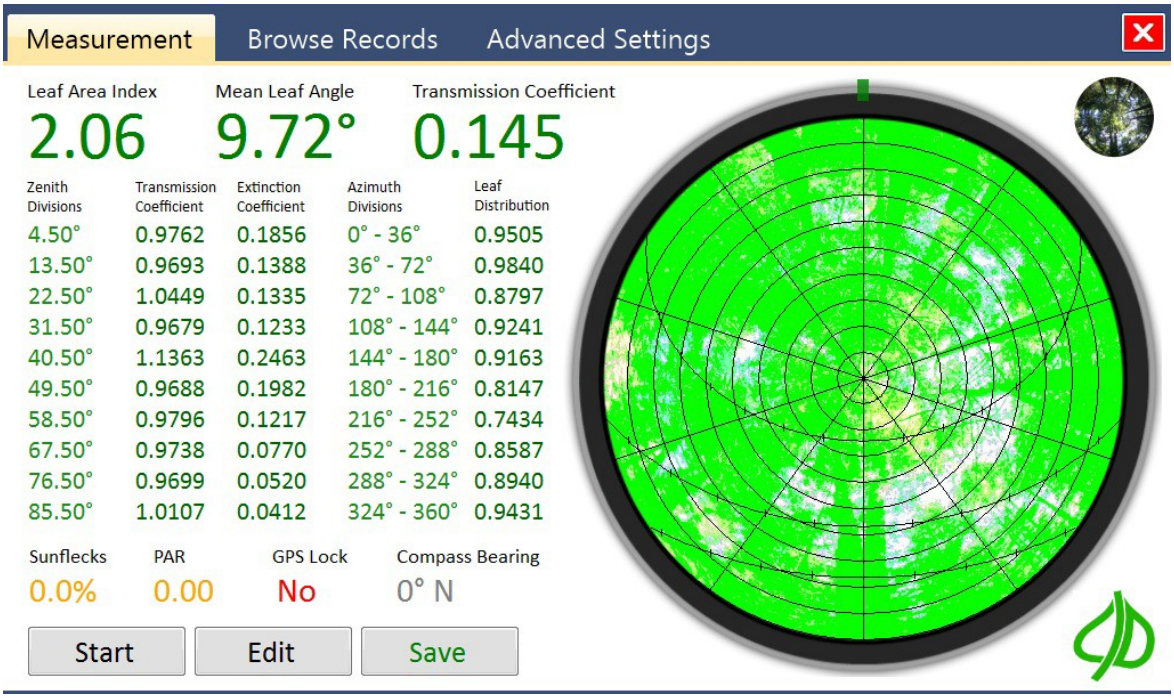
7. Click ***Data*** and ***Edit*** to view your measurement details

and make changes.

8. 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. Alternatively, the trigger button on the arm of the CI-110 can be used to save an image.
   The trigger button on the wand of CI-110 will automatically save an image. If this is pushed before starting the live preview of the image by selecting the ***Start*** button, the image will save immediately upon enabling the live preview.

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/Update 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.

Previously saved images can be opened back up in the software and edited. When opening a previously saved image the Save button will change to Update. After making desired changes to the image, click on Update to save over the original image with the newly edited image.

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

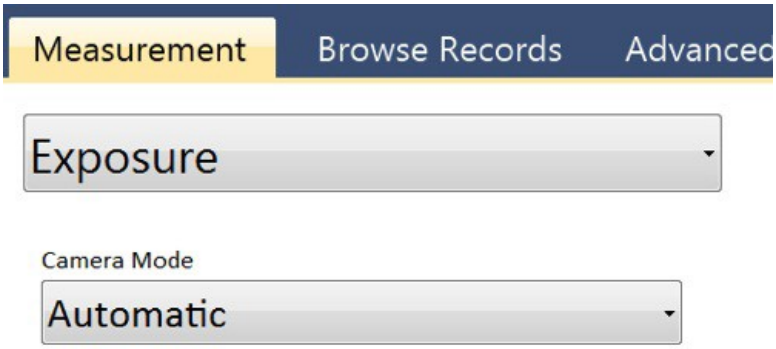
This indicates if there is a GPS satellite lock on your current position. Records saved without a GPS Lock may store the wrong GPS location, or no GPS location. The text will toggle from a red “No” to green “Yes” when a GPS lock has been acquired. The CI-110 should be outside or near a window to get 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

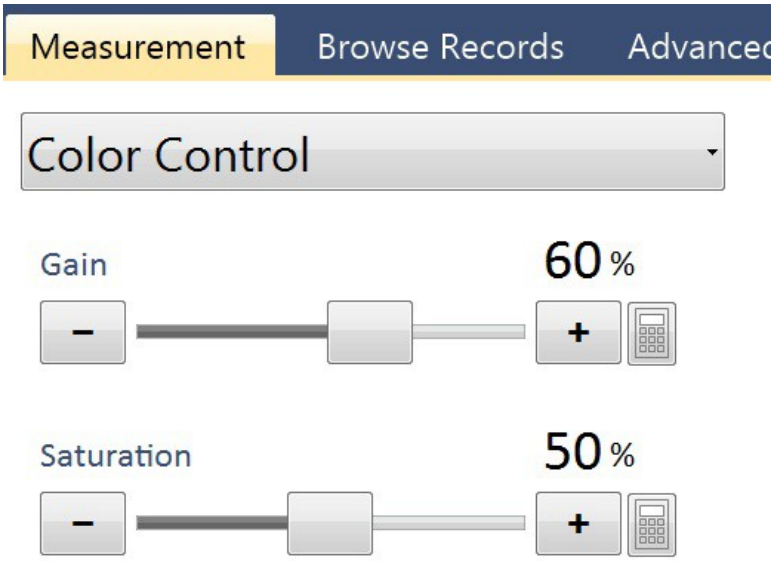
user to adjust the exposure and see the affect directly in the image.



Color Control

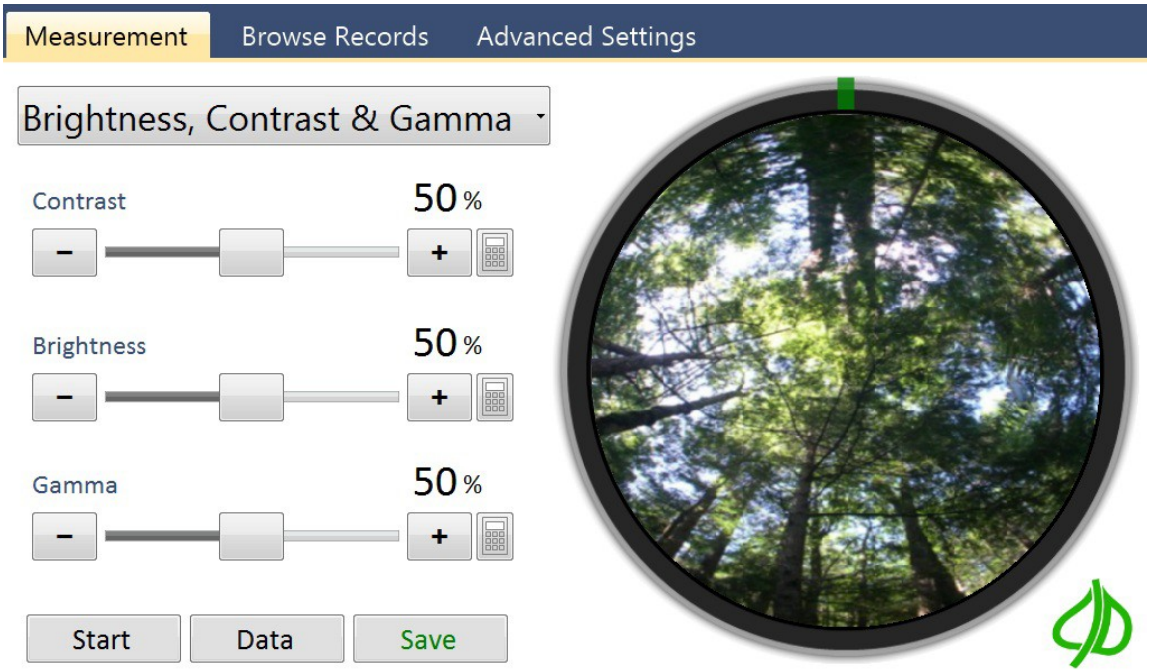
This feature is used to optimize the image colors for accurate processing. If needed, the color control gain and saturation levels can be adjusted to help render leaf elements as green and sky elements as blue.

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.


Measurement
Browse Records
Advanced
Color Control
Gain
60 %
Saturation
50 %

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.


Measurement
Browse Records
Advanced Settings
Brightness, Contrast & Gamma
Contrast
50 %
–
+
Brightness
50 %
–
+
Gamma
50 %
–
+
Start
Data
Save

Contrast

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

Brightness

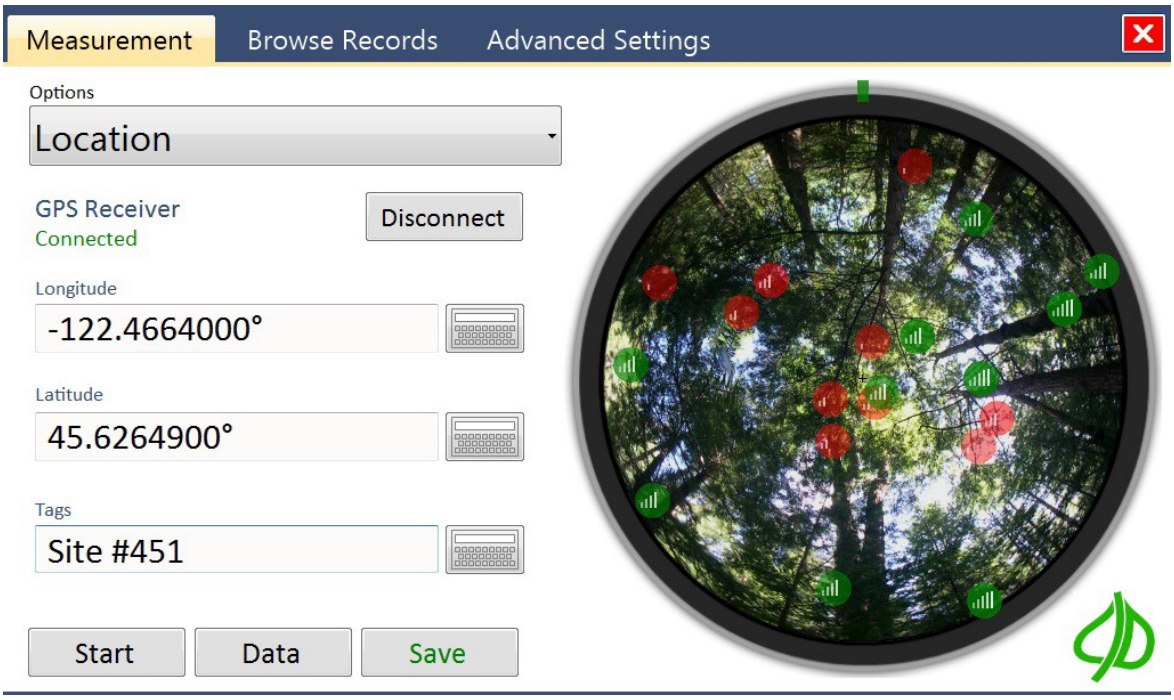
Controls the luminance of the measurement image.

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.



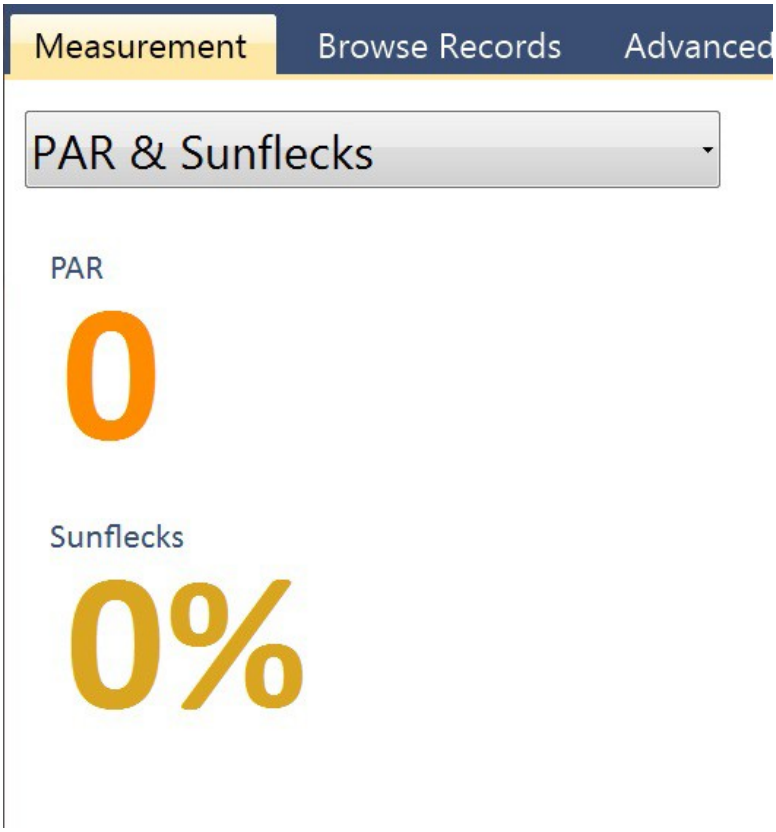
Longitude and Latitude

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 µmol/m^2 s. Adjustments to the PAR and sunfleck calibrations can be made through the Advanced Settings tab.

PAR LAI Calculation

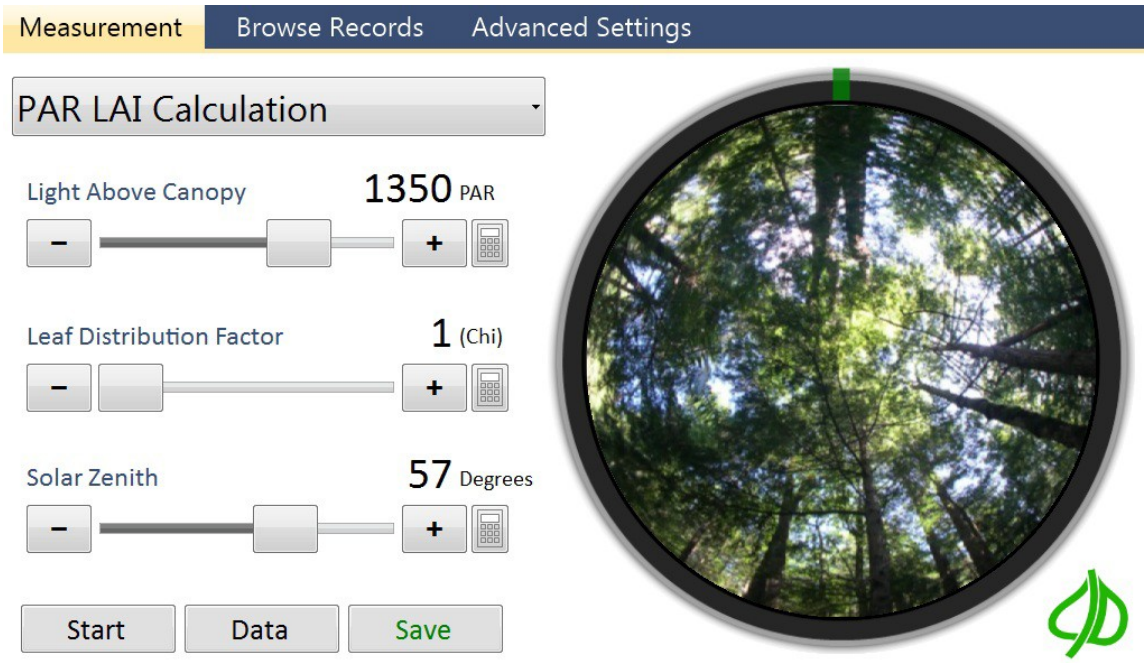
This screen is used to change the way PAR data is recoded. The PAR LAI calculation is fully dependent on the user entered data and does not rely on the hemispherical image for this data output. Several factors are possible to adjust by the user: light above the canopy, leaf distribution factor and the 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 $\mu mol/m^2$ 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

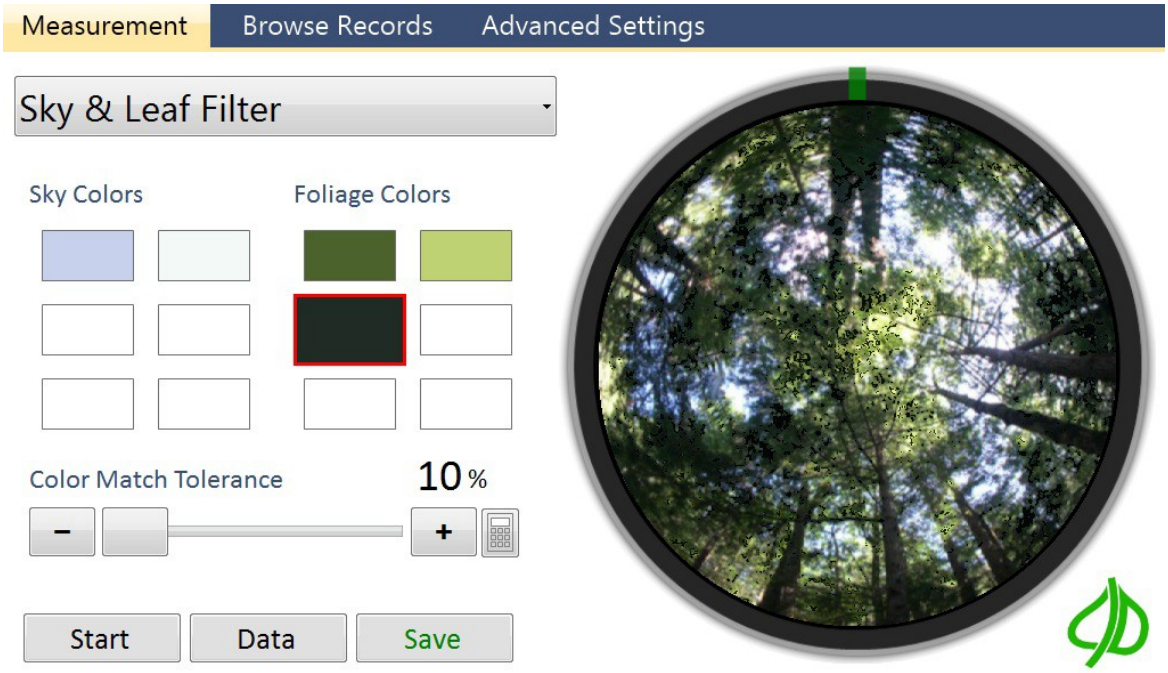
factor, such as maize (0.7-2.5). The leaf distribution factor does not produce significant error in the LAI equation.

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.



Sky & Leaf Filter

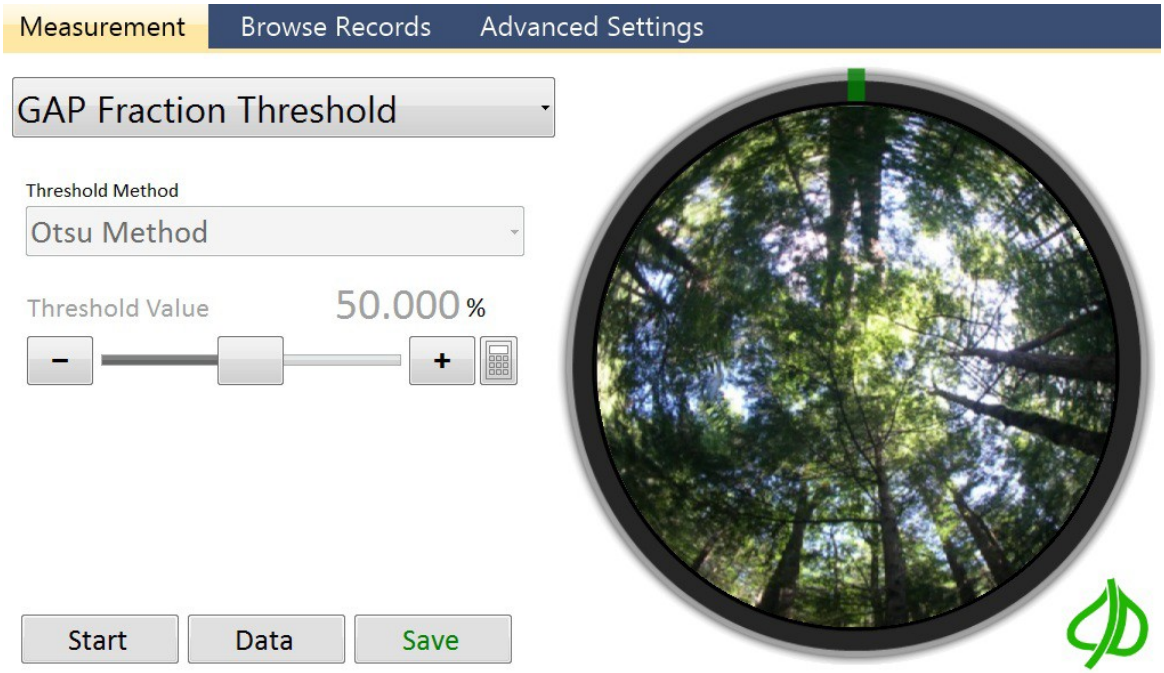
This feature allows users to darken specific colors (foliage area) and lighten others (sky area). In the example below foliage colors that should be green are blurred by the sky with a blue hue. After applying the Sky & Leaf Filter the second image shows those areas are darkened so they will be counted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



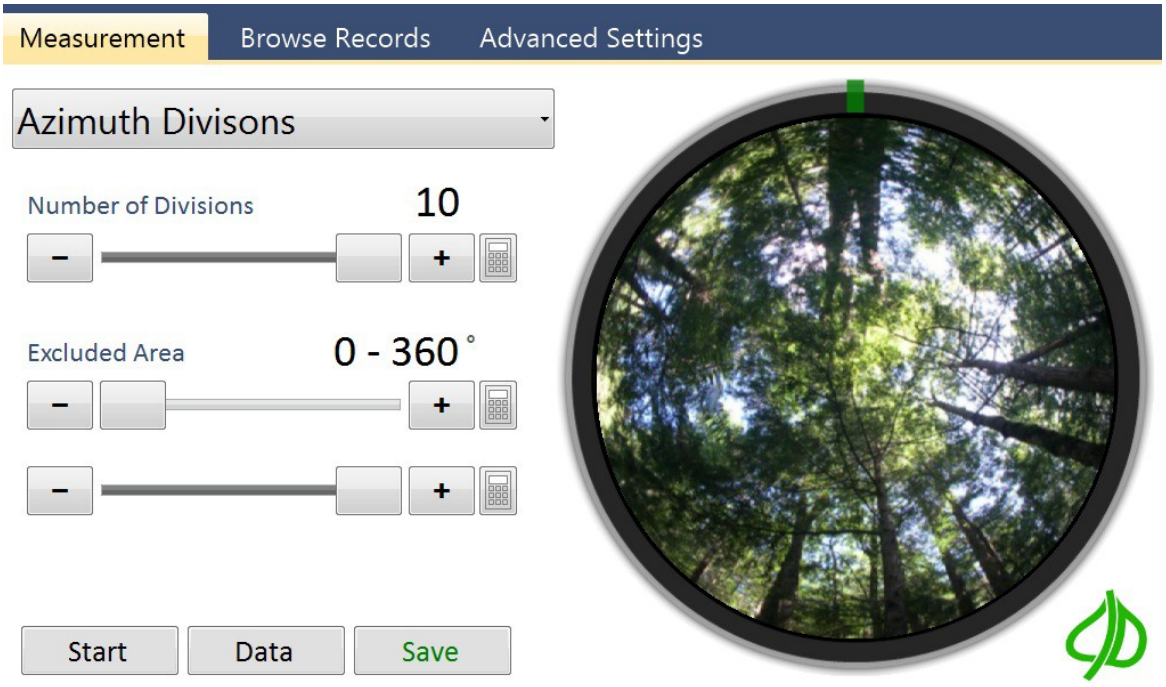
The choice of appropriate Gap Fraction method is left to the discretion of the user. It is recommended to experiment and use the threshold method that best separates canopy

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.

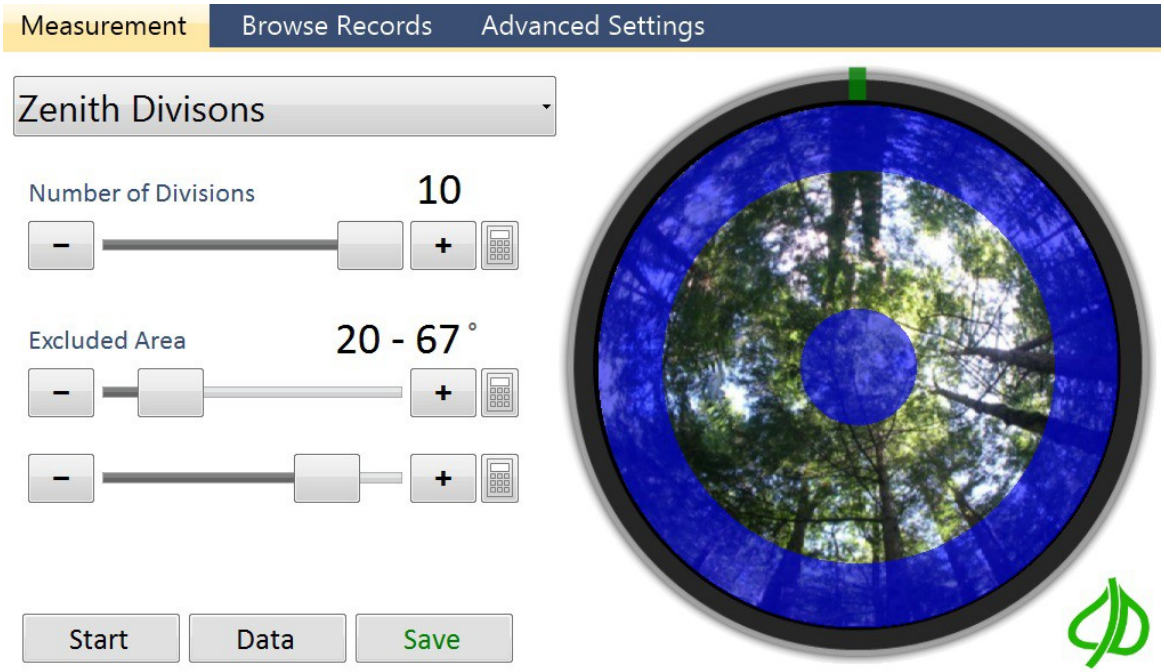
Measurements can automatically be split into up to 10 azimuth divisions.

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

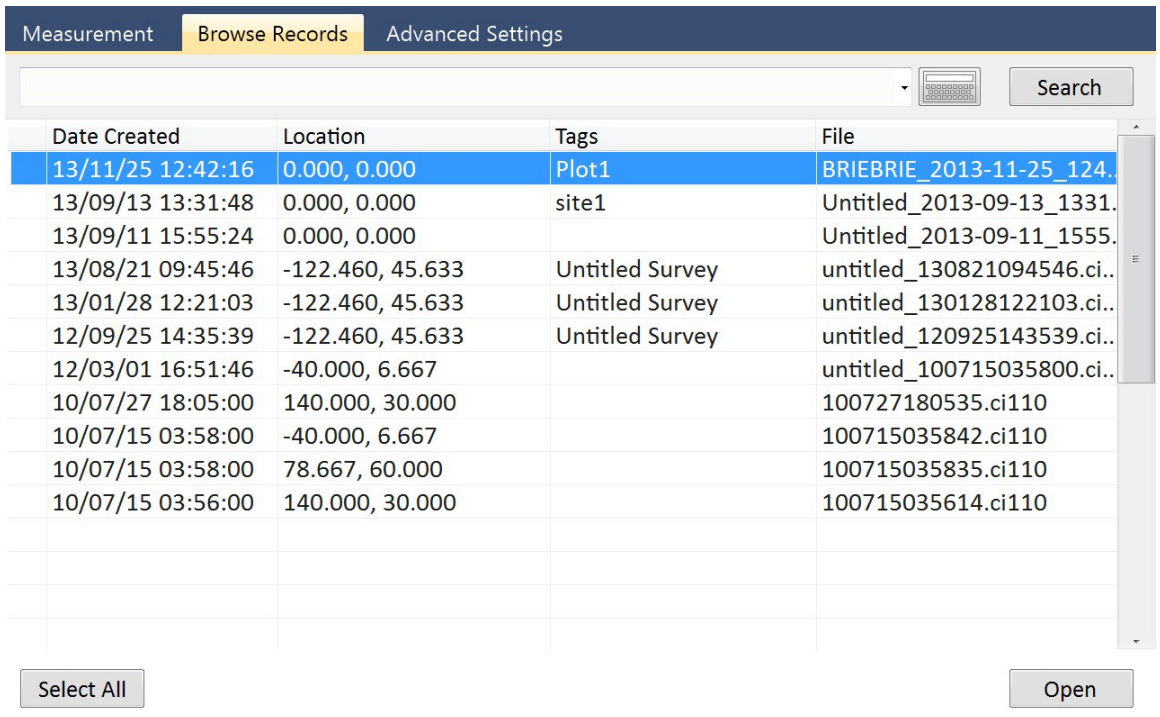
These fields indicate which part of the camera image should be measured. The area masked in blue will be excluded. In addition to using the slider controls users can select using their finger by sliding a finger clockwise over the area to exclude, or counter clockwise over the area to exclude.

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

> 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).

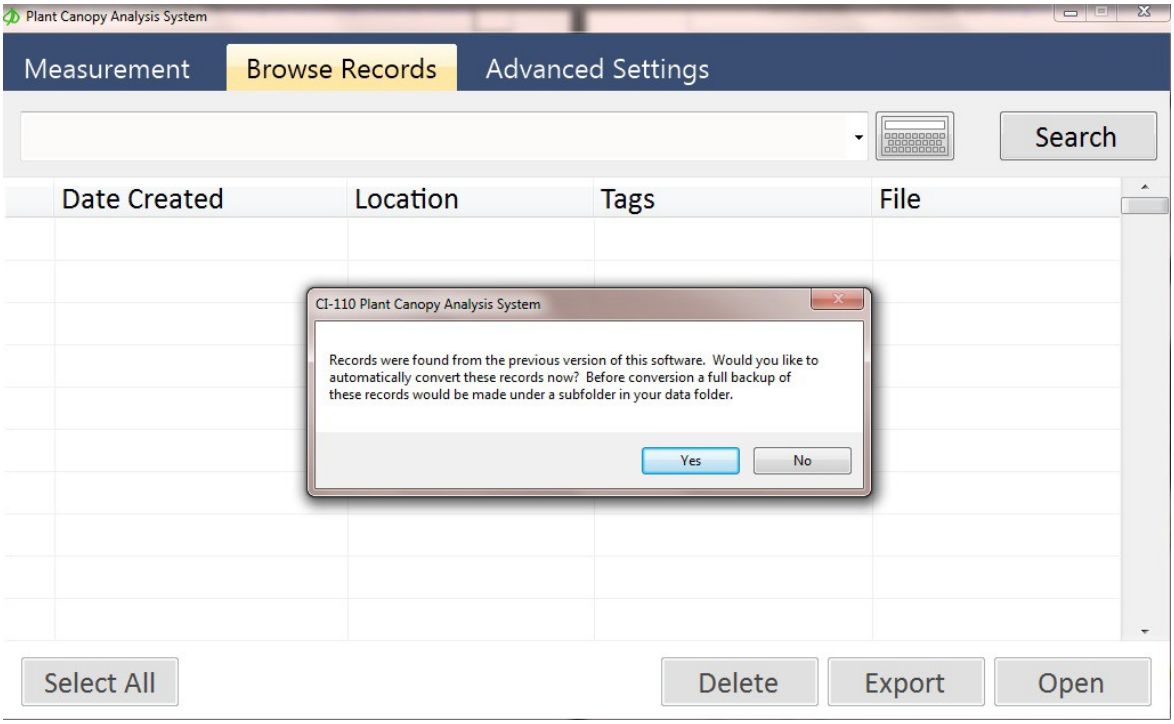
Search Keywords

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.

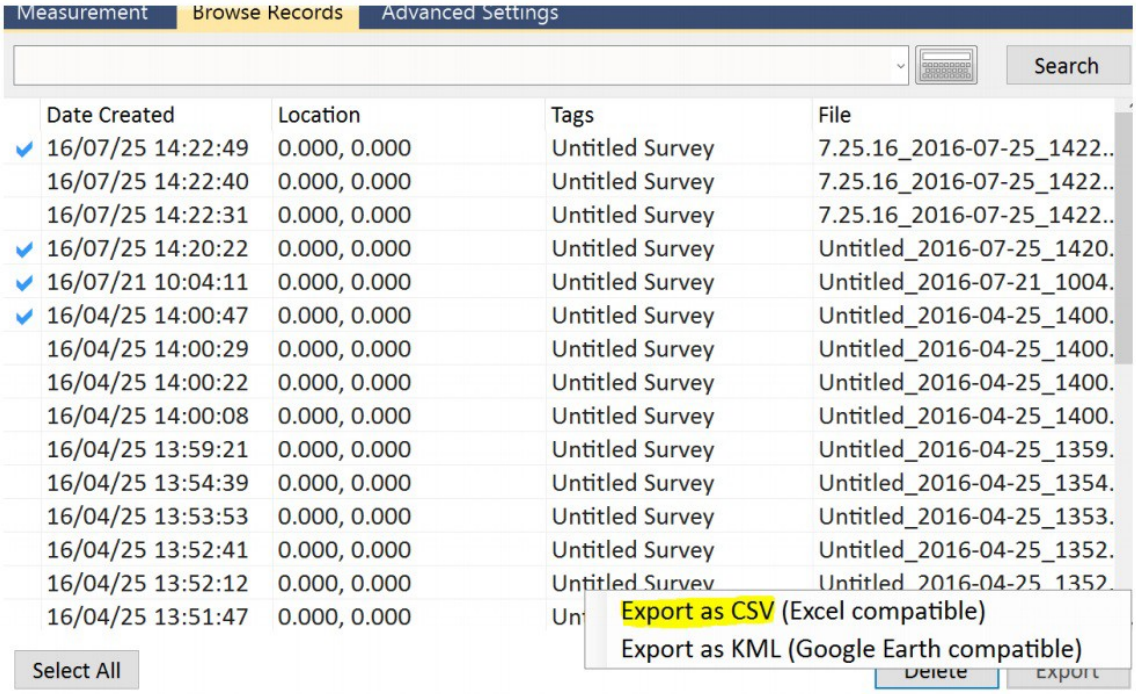
If records are found from a previous version of the software, you will be asked “Would you like to automatically convert these records now?” Before conversion, a full backup of these records will be made under a subfolder in your data folder. If you remove the *.ci110 filename extension*, the record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

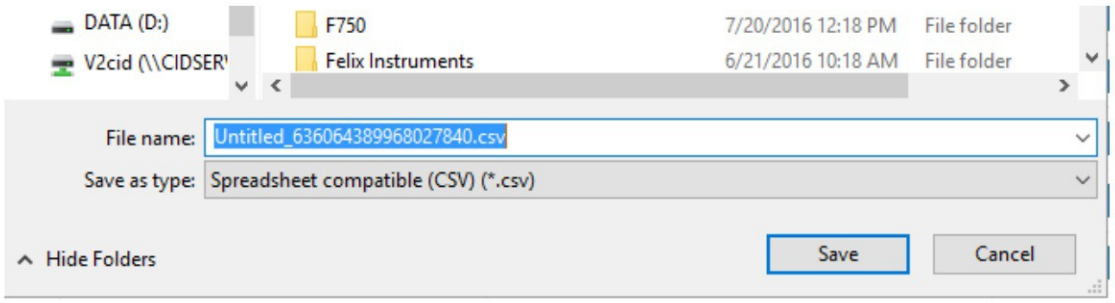


Exporting to excel

Navigate to the Browse Records tab, select the files for export and click on the Export button. There are two formats for export: CSV and KML. To work with data in Excel, opt for CSV format (comma separated values).

Select a name and location for the CSV file and open the file in Excel.

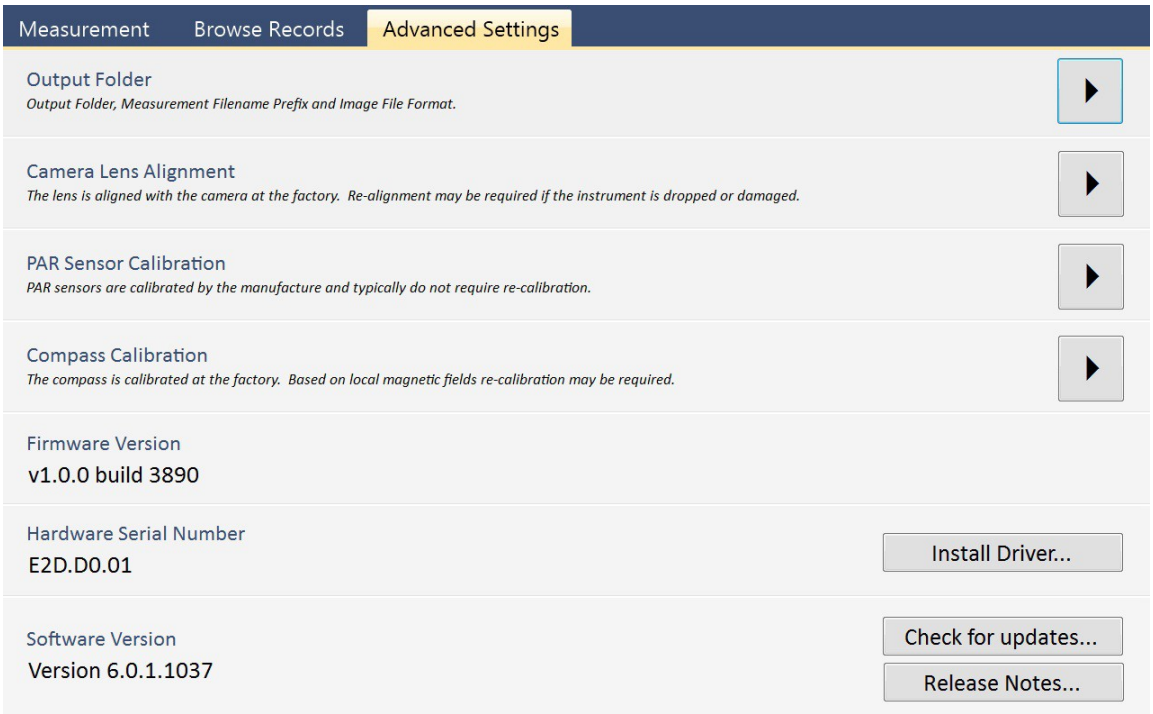

Measurement
Browse Records
Advanced Settings
Search
Date Created
Location
Tags
File
16/07/25 14:22:49 0.000, 0.000 Untitled Survey 7.25.16_2016-07-25_1422..
16/07/25 14:22:40 0.000, 0.000 Untitled Survey 7.25.16_2016-07-25_1422..
16/07/25 14:22:31 0.000, 0.000 Untitled Survey 7.25.16_2016-07-25_1422..
16/07/25 14:20:22 0.000, 0.000 Untitled Survey Untitled_2016-07-25_1420.
16/07/21 10:04:11 0.000, 0.000 Untitled Survey Untitled_2016-07-21_1004.
16/04/25 14:00:47 0.000, 0.000 Untitled Survey Untitled_2016-04-25_1400.
16/04/25 14:00:29 0.000, 0.000 Untitled Survey Untitled_2016-04-25_1400.
16/04/25 14:00:22 0.000, 0.000 Untitled Survey Untitled_2016-04-25_1400.
16/04/25 14:00:08 0.000, 0.000 Untitled Survey Untitled_2016-04-25_1400.
16/04/25 13:59:21 0.000, 0.000 Untitled Survey Untitled_2016-04-25_1359.
16/04/25 13:54:39 0.000, 0.000 Untitled Survey Untitled_2016-04-25_1354.
16/04/25 13:53:53 0.000, 0.000 Untitled Survey Untitled_2016-04-25_1353.
16/04/25 13:52:41 0.000, 0.000 Untitled Survey Untitled_2016-04-25_1352.
16/04/25 13:52:12 0.000, 0.000
16/04/25 13:51:47 0.000, 0.000
Export as CSV (Excel compatible)
Export as KML (Google Earth compatible)
Select All
Delete
Export


DATA (D:)
V2cid (\\CIDSER
F750 7/20/2016 12:18 PM File folder
Felix Instruments 6/21/2016 10:18 AM File folder
File name: Untitled_63606438968027840.csv
Save as type: Spreadsheet compatible (CSV) (*.csv)
Hide Folders
Save
Cancel

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.



Output Folder

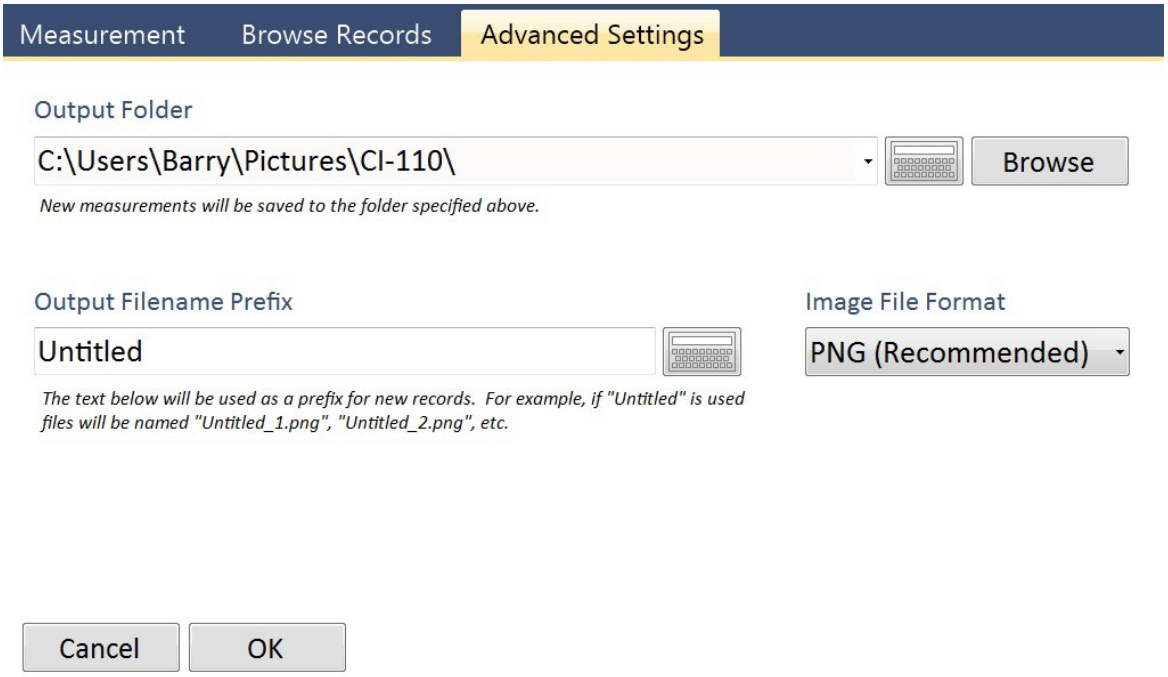
The *Output Folder* textbox contains the path to store measurement records (see *Application Output*). Use the ***Browse*** button to change the output folder by browsing to your selection.

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*).



Application Output

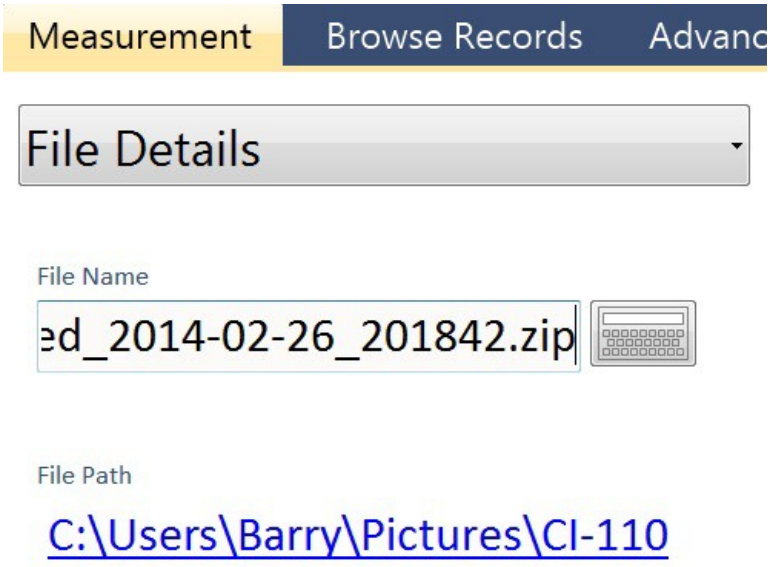
By default CI-110 images and data will be stored under the Windows user's Documents folder in a subfolder called *CI-110.* Each measurement is saved as a *.ci110* file. Within the *.ci110* file, there are three separate files that can be accessed by re-naming the record in the CI-110 software. The three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

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

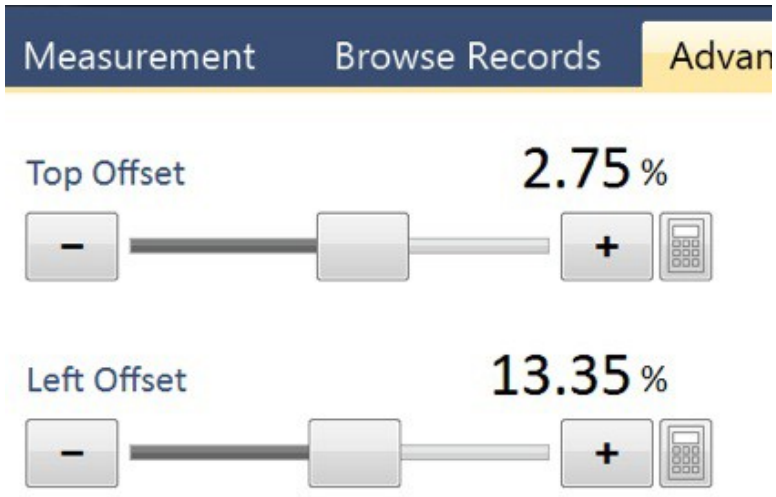
- Threshold method
- Sky and leaf filter details
- PAR
- Sunflecks
- Leaf area index
- Mean leaf angle
- Gap fraction
- Leaf distribution factor (chi)
- PAR above canopy
- Solar zenith

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.

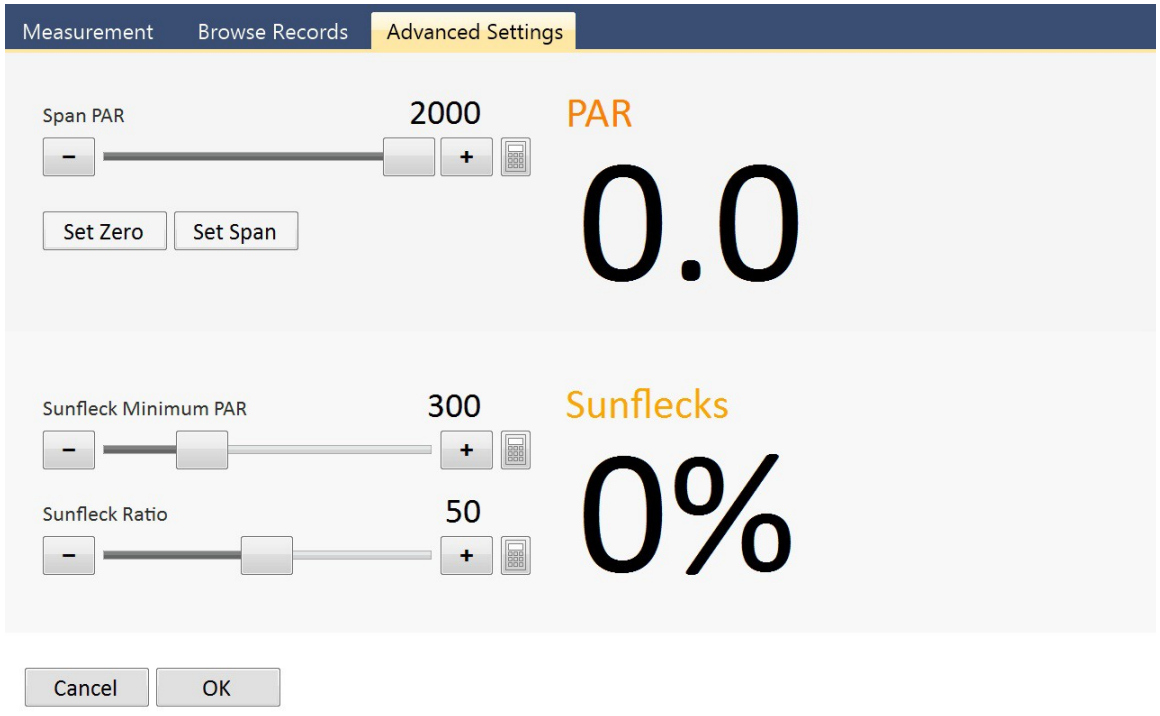
The images are automatically aligned by the software from a factory calibration of the offset. This offset is to the optical center of the fisheye camera lens.

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*.



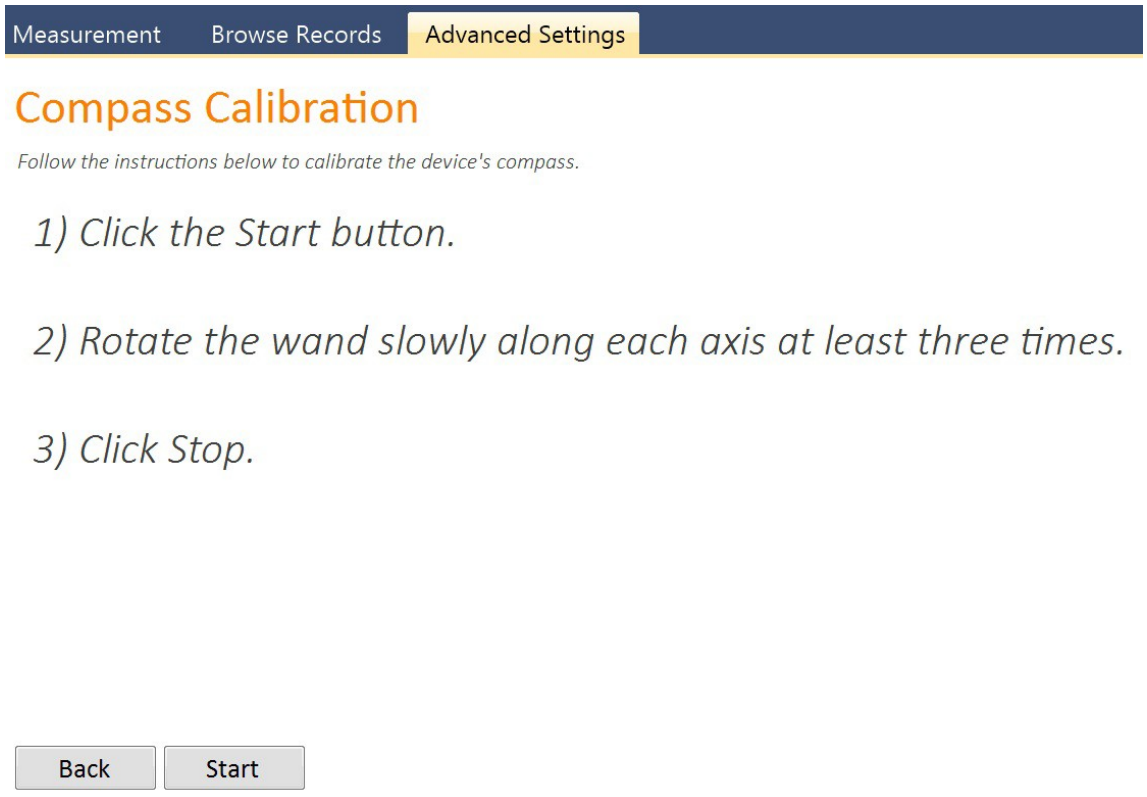
PAR Sensor Calibration

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*.



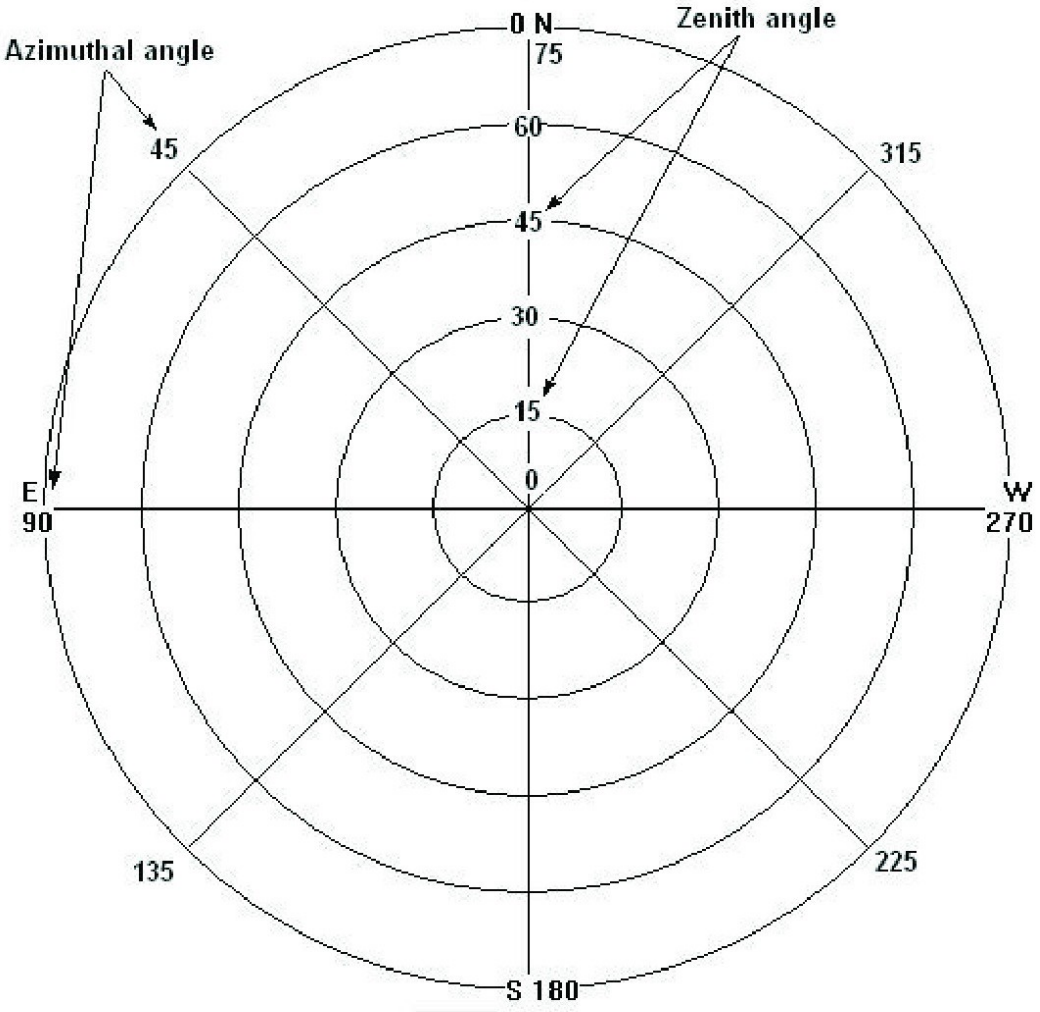
Compass Calibration

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.



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).


Azimuthal angle
Zenith angle
0 N
75
60
45
30
15
0
45
315
E
90
W
270
135
225
S 180

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 follow:

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

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

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

$K\varphi_i = 1$ *for horizontal leaves* $x \to \infty$

$K\varphi_i = \frac{2\tan\varphi_i}{\pi}$ *for vertical leaves* $x \to 0$

$K\varphi_i = \frac{1}{2\cos\varphi_i}$ *for spherical leaves* $x \to 1$

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

$\alpha = tan\text{-}1\ x\ (0° \le \alpha \le 90°)$

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

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. Include the serial number of the instrument in the email support request.

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

Website:

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?

   The latest version of software and the driver can be downloaded at 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*.

   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?

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?

   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

   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?

   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?

   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?

   - 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.

- 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?

   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?

   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?

    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?

    - New and improved camera and filter.
    - New and improved GPS.
    - Updated software with many bug fixes.

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

    To access the Log Files:

i. Start the CI-110 software
ii. Press ***Control*** and ***Escape*** at the same time or ***Ctrl + 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 try/notification area and the start menu button at the bottom of the screen). Select ***Start Task Manager*** from the list.

iii. From the *Task Manager*, click on the *Processes* tab.

iv. Right click on *CID.CI110.exe* and select ***Open File Location*** (this launches the file browser)

v. You should see several *ApplicationLog* and *ErrorLog* files.

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

To calibrate the Sol Tab tablet daylight visible touch screen:

i. Go to ***Start*** and ***Control Panel***

ii. Go to ***Hardware and Sound***

iii. Under ***Tablet PC Settings***, choose ***Calibrate the screen for pen or touch input***

iv. Click the ***calibrate*** button

v. Follow the instructions to touch the screen and choose to save the calibration data.

14. Which Gap Fraction Method should I use?

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?

    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?

    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 and the Acer tablet computer both have 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 many 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

Test Date: **Serial Number:**

Par Sensor Calibration

PAR Zero Calibration:

PAR Span Calibration:

Sunflecks Zero Calibration:

Sunflecks Span Calibration:

Compass, Lens, and Camera Settings

Top Offset: Left

Offset:

Comments: