

# ***DSAIL-TreeVision Software v1.0.1***

## **User Guide 2023**

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### **1 Licence**

*DSAIL-TreeVision* software is licensed under the [Apache Licence, Version 2](#).

### **2 About Us**

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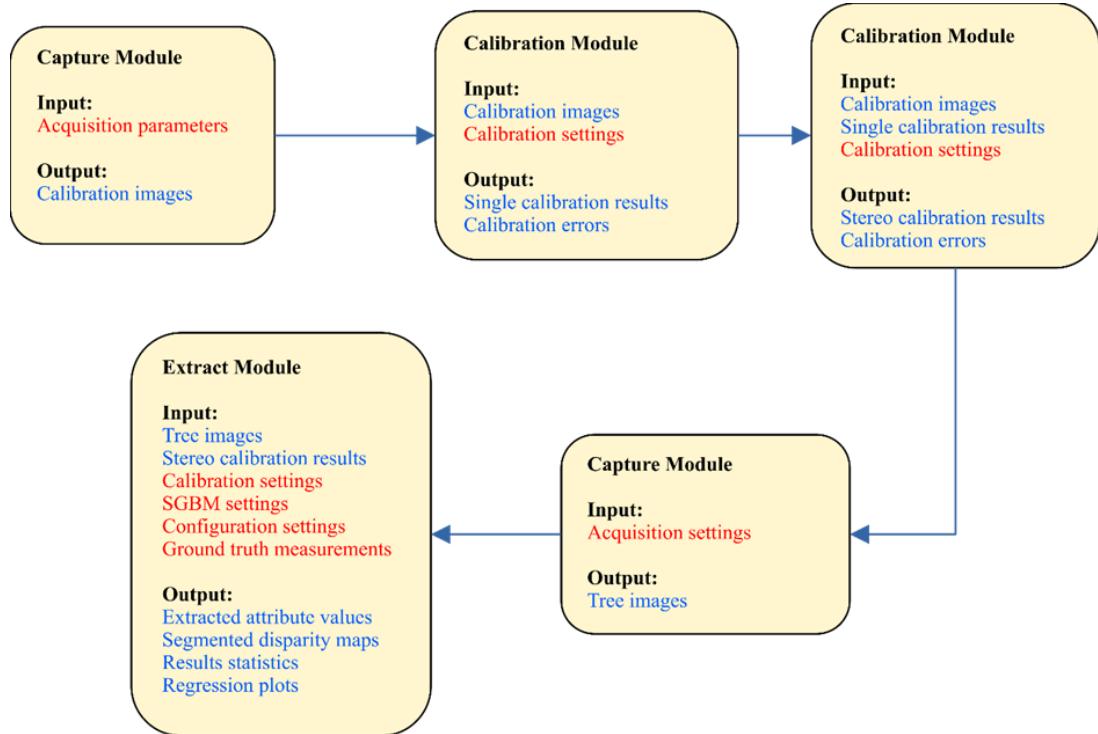
### **3 Acknowledgements**

The developers thank NVIDIA Corporation for a hardware grant to the Centre for Data Science and Artificial Intelligence (DSAIL) and Safaricom PLC for funding the Integrated Forest Monitoring project.

### **4 Installation**

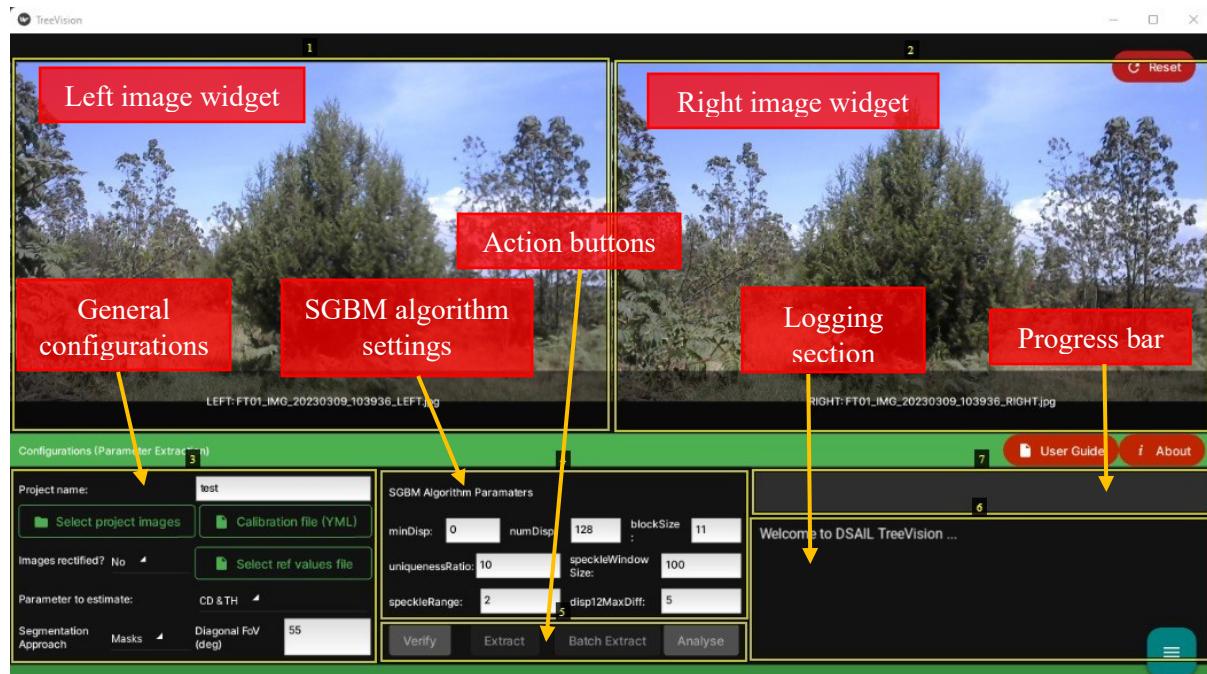
Visit [DSAIL-TreeVision's GitHub repository](#) for instructions on how to install it. For Window's users, we advise that you install [Git Bash](#) before beginning the installation process to make process nice and smooth.

## 5 Using DSAIL-TreeVision: The Workflow

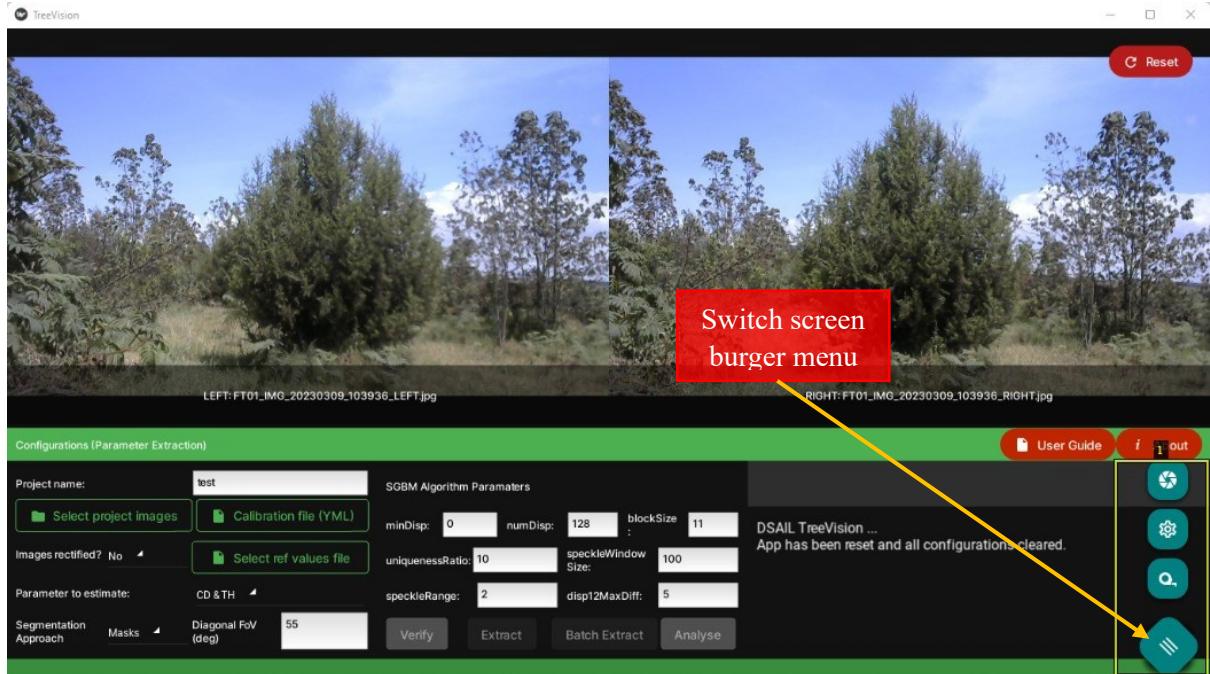


### 5.1 DSAIL-TreeVision Extract Module

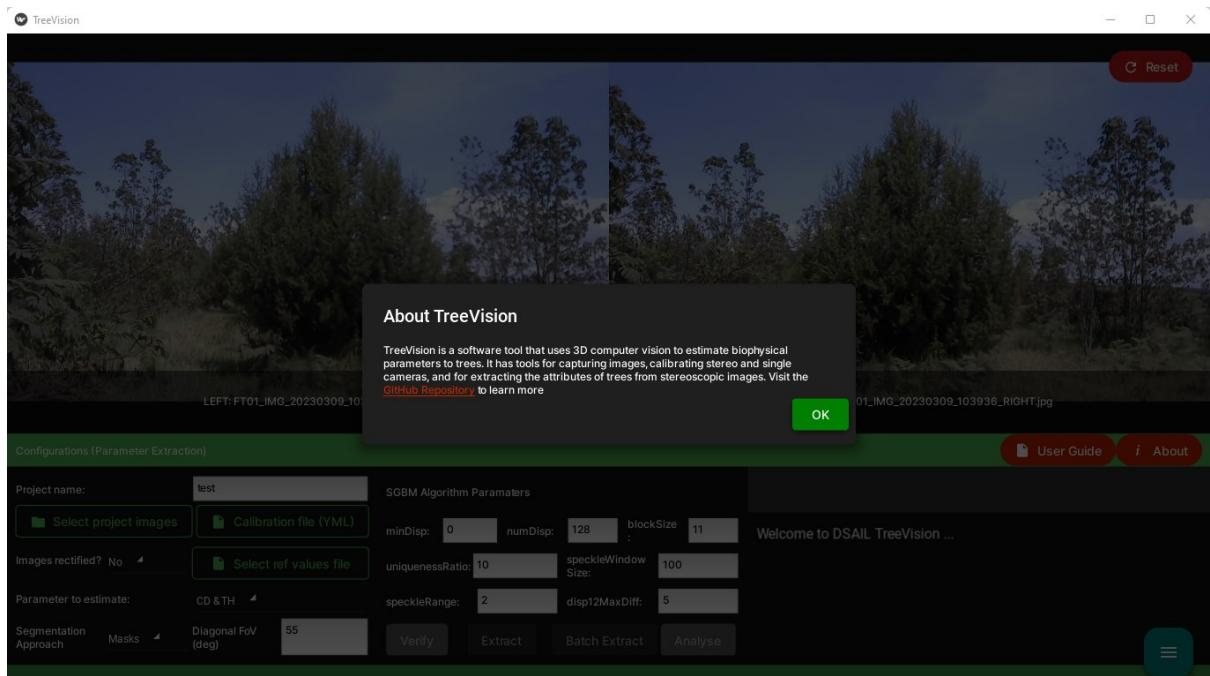
This is main module of *DSAIL-TreeVision* and is used to extract the diameter at breast height (DBH), crown diameter (CD) and tree height (TH) of trees from stereoscopic images. For DBH extraction, it is preferable to provide close range images of tree trunks of fully grown trees rather than images of whole trees. For CD and TH, provide images of whole trees. The user interface of this module is as shown below.



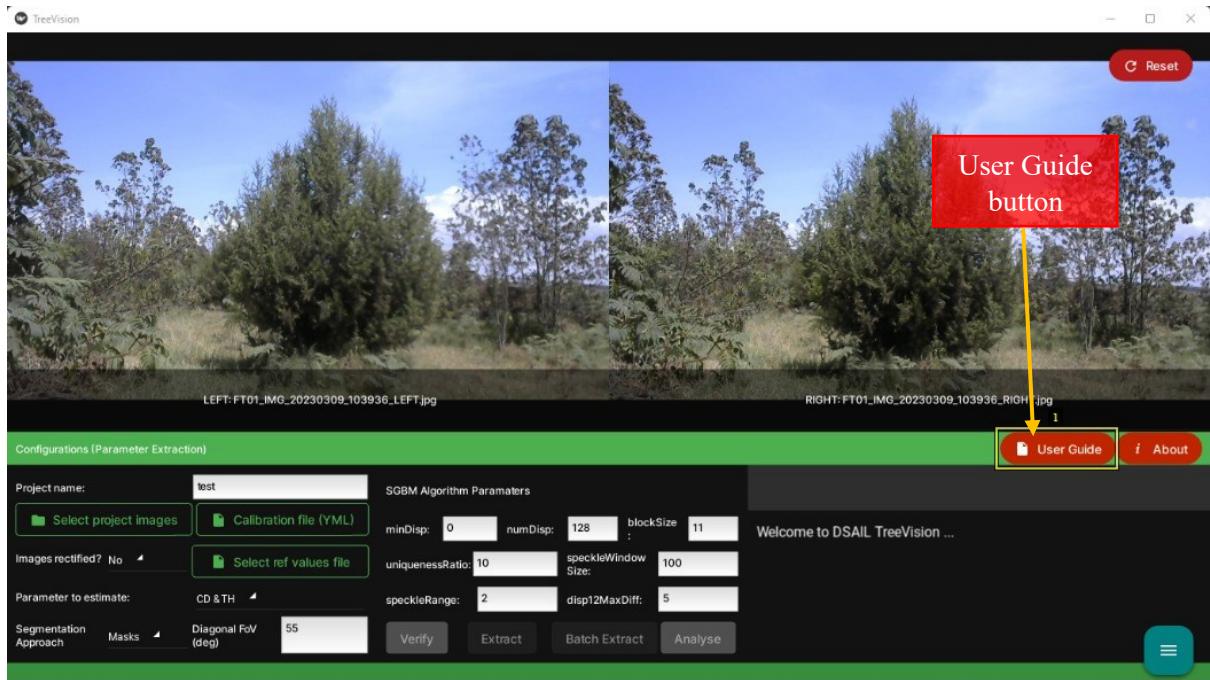
To switch between the three modules, click on the **switch screen burger button** highlighted in the figure below. Upon clicking, it opens to show a stack of three more buttons for switching between the three modules.



You can find some information about *DSAIL-TreeVision*, click on the About button and a popup modal with some information will be displayed. In the text displayed is included a link which, on clicking, leads to the software tool's [GitHub repository](#).

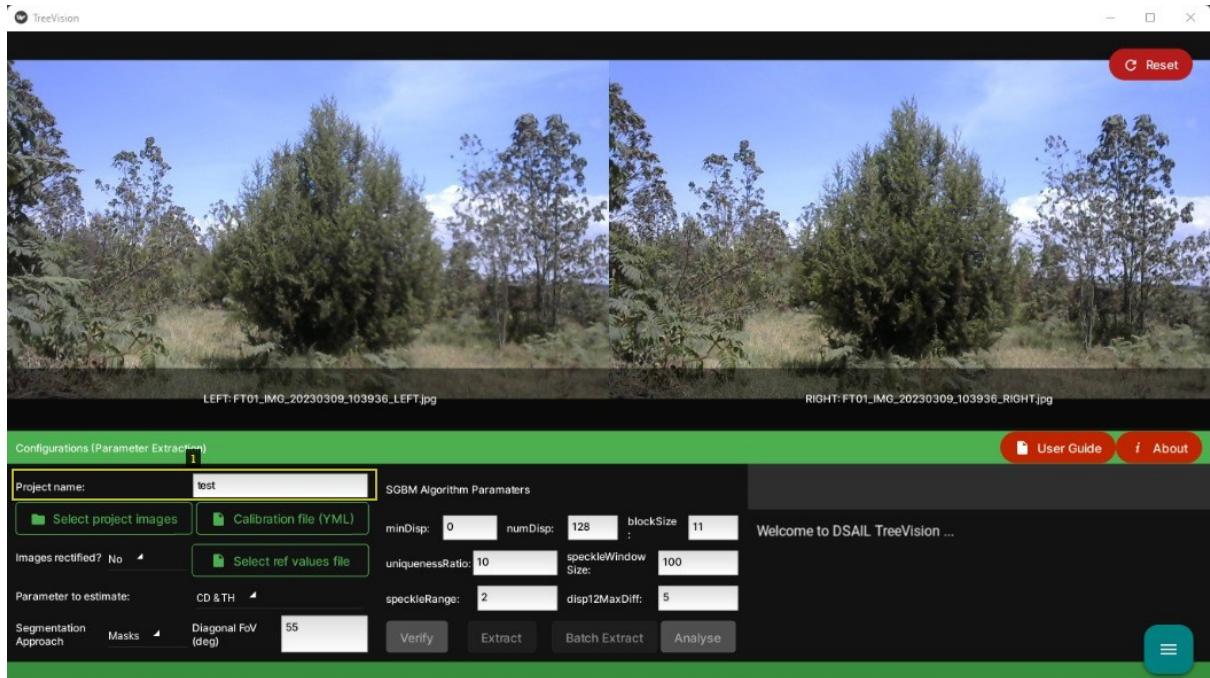


You can open this user guide when using DSAIL-TreeVision by clicking on the User Guide button and the guide will be opened in your platform's default PDF reader.

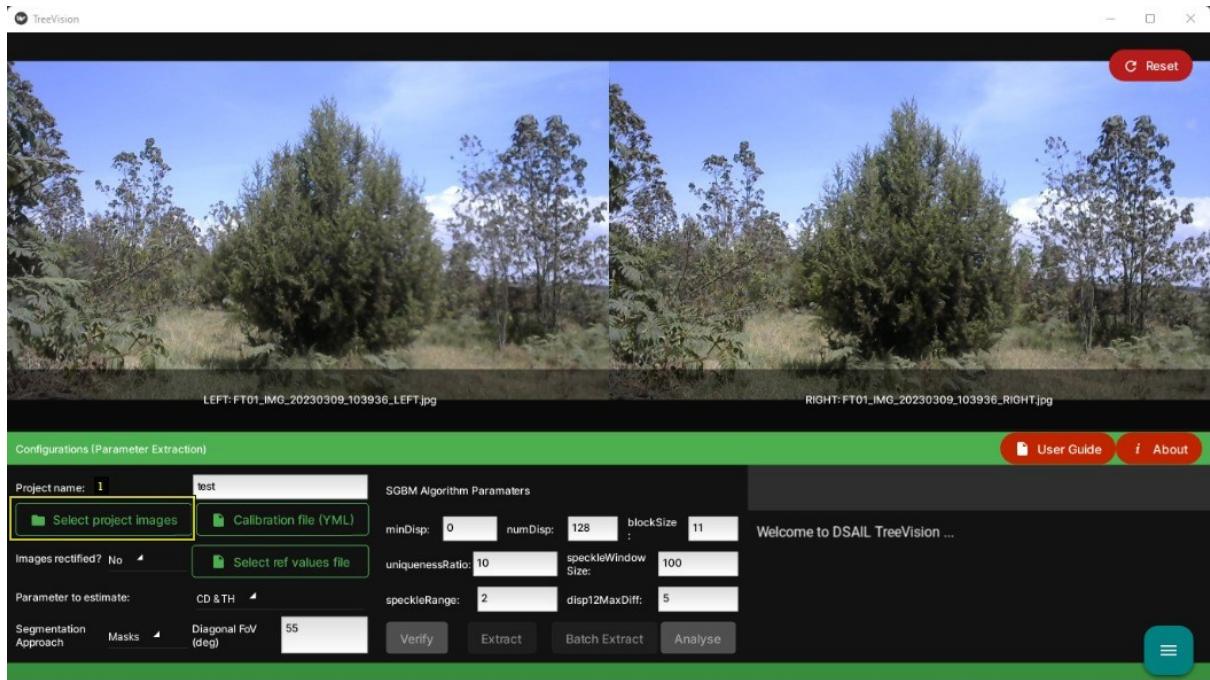


To extract tree biophysical parameters using this module, follow the following steps:

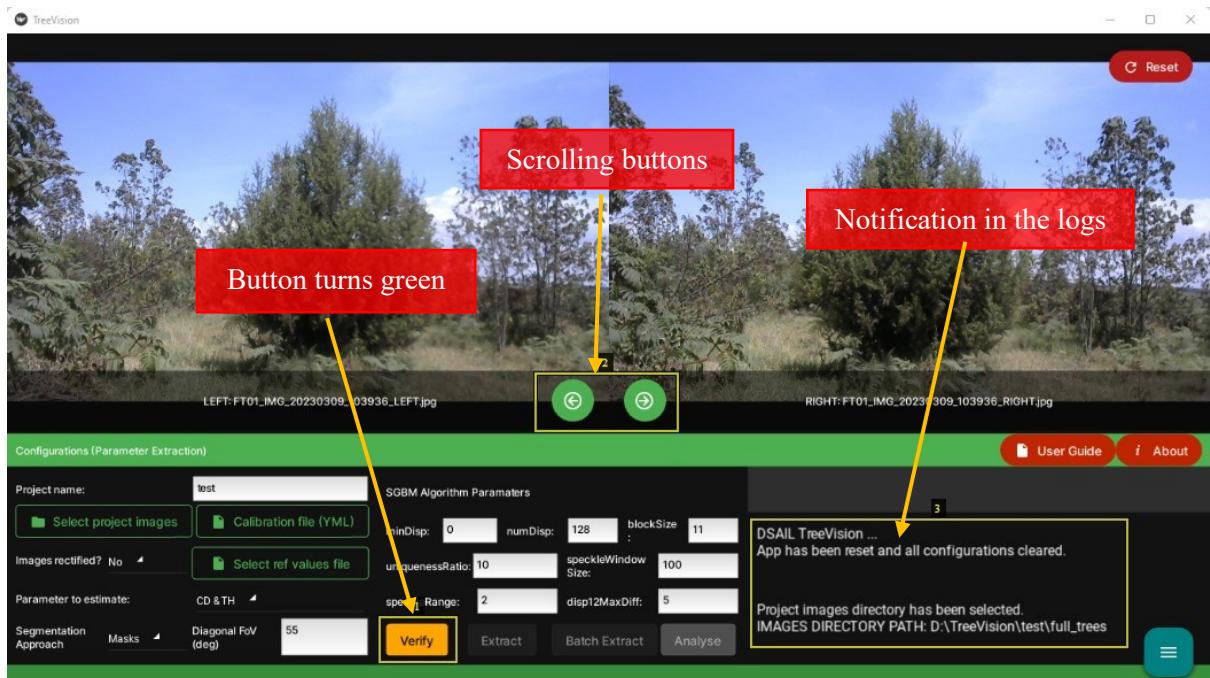
- Provide the name of the project you are working on by filling in the **Project name** text field.



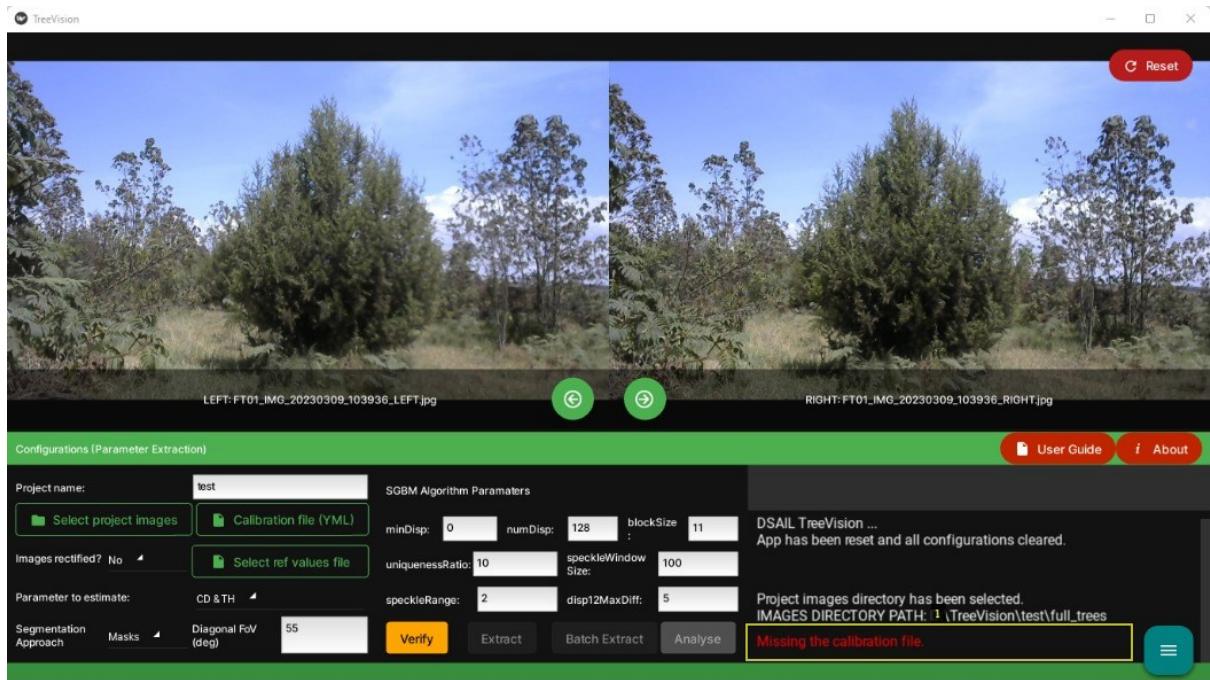
- Load the images by clicking the **Select project images** button and navigating to the right directory. To select the folder, navigate into it and click on the **check mark** button at the bottom right of the user interface.



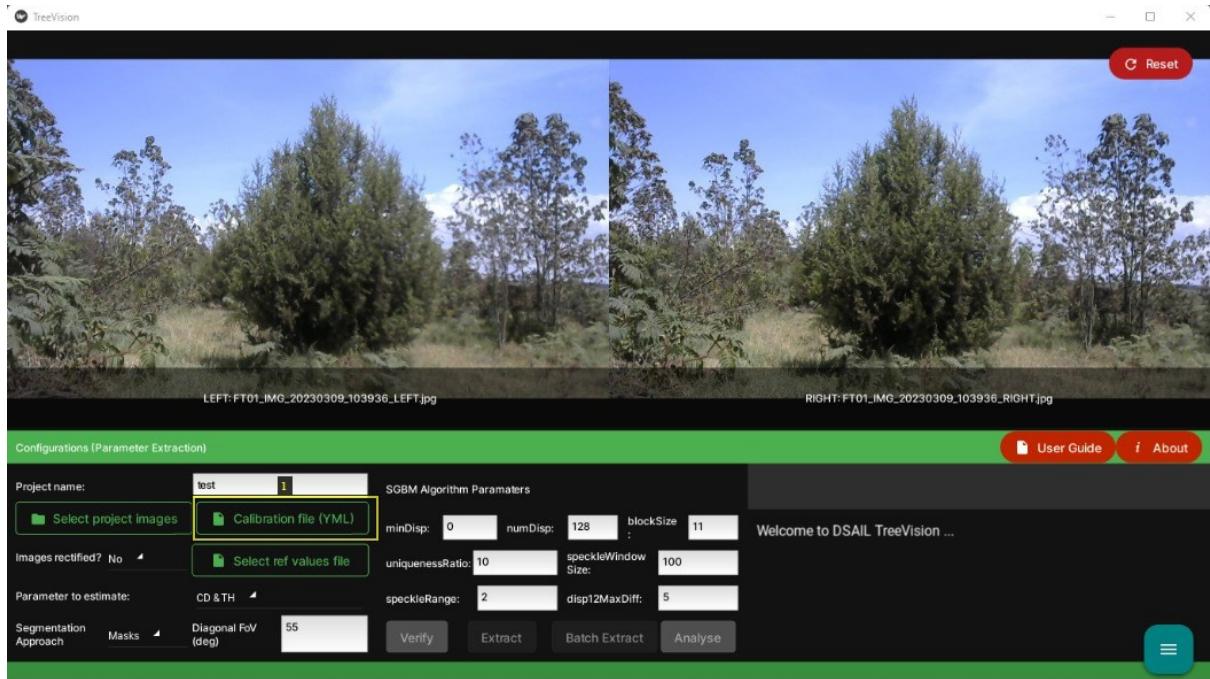
Notice that once the folder of paired images has been selected, there is a notification in the logging section about it, the **Verify** button which was previously deactivated turns green, and you now have buttons for scrolling through the sequence of images. The **Verify** button checks that all the user inputs are valid.



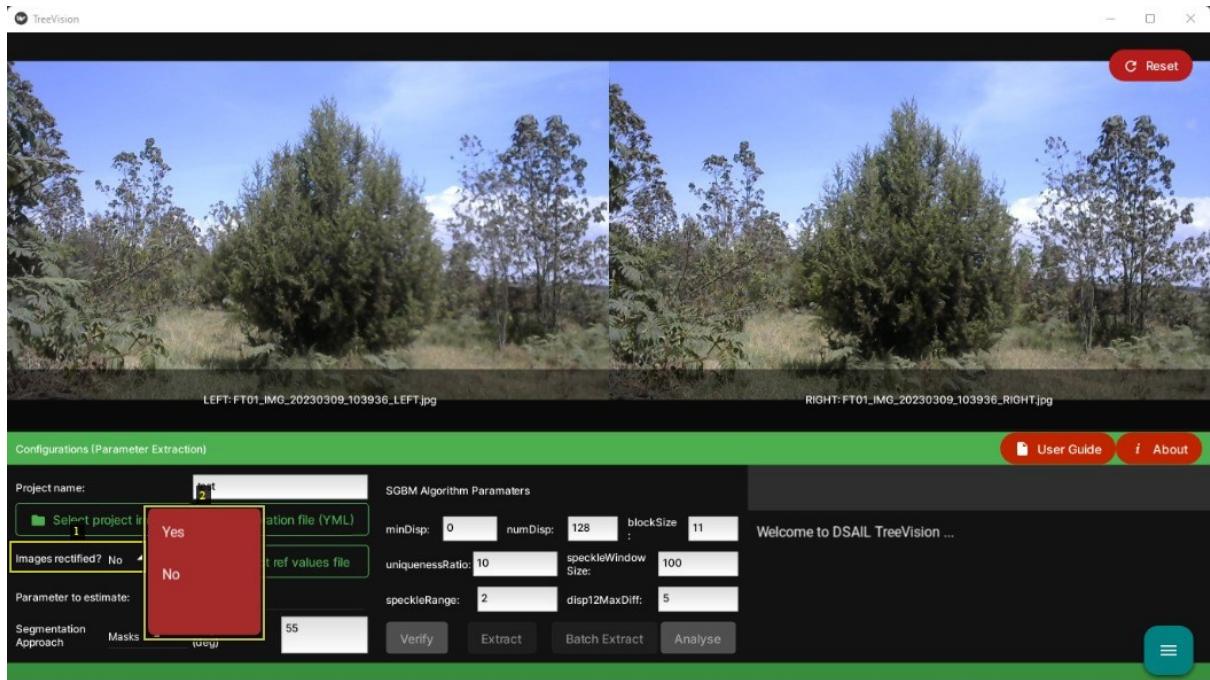
- If you now click on the **Verify** button, a notification will be shown in the logging window reminding the user that they need to upload a camera calibration file. Other errors stemming from the user inputs are also displayed in the notification section if the verification is not successful.



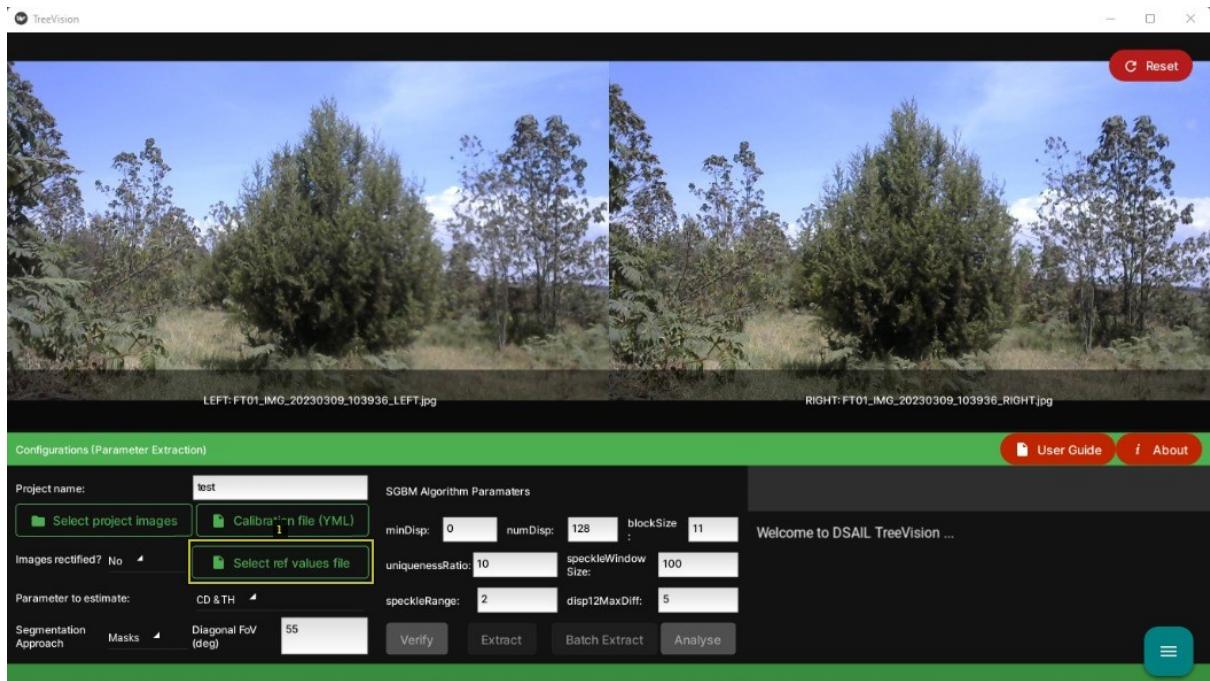
- iv. Load the stereo camera calibration file by clicking the **Calibration file (YML)** button and navigating to the location of the file. To select the file, click on it. There will be a notification in the logging section that the camera file has been selected.



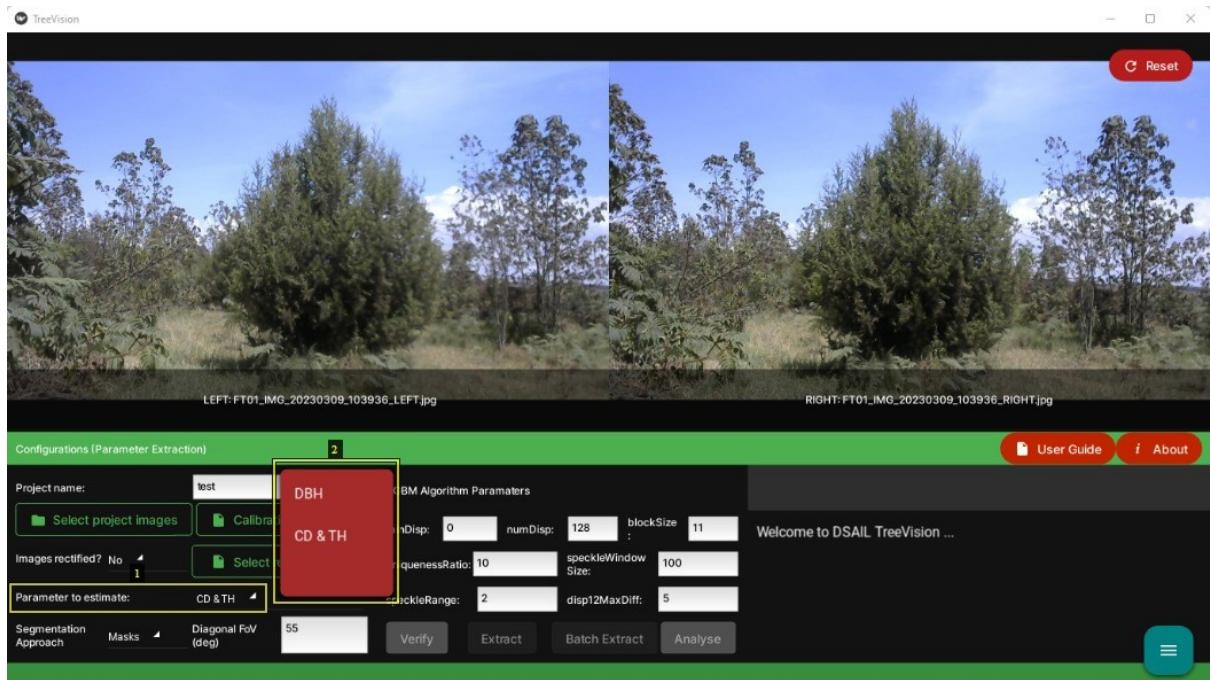
- v. If the images you loaded in step ii above are already rectified, choose Yes from the **Images rectified?** dropdown list. Otherwise, leave the option as No.



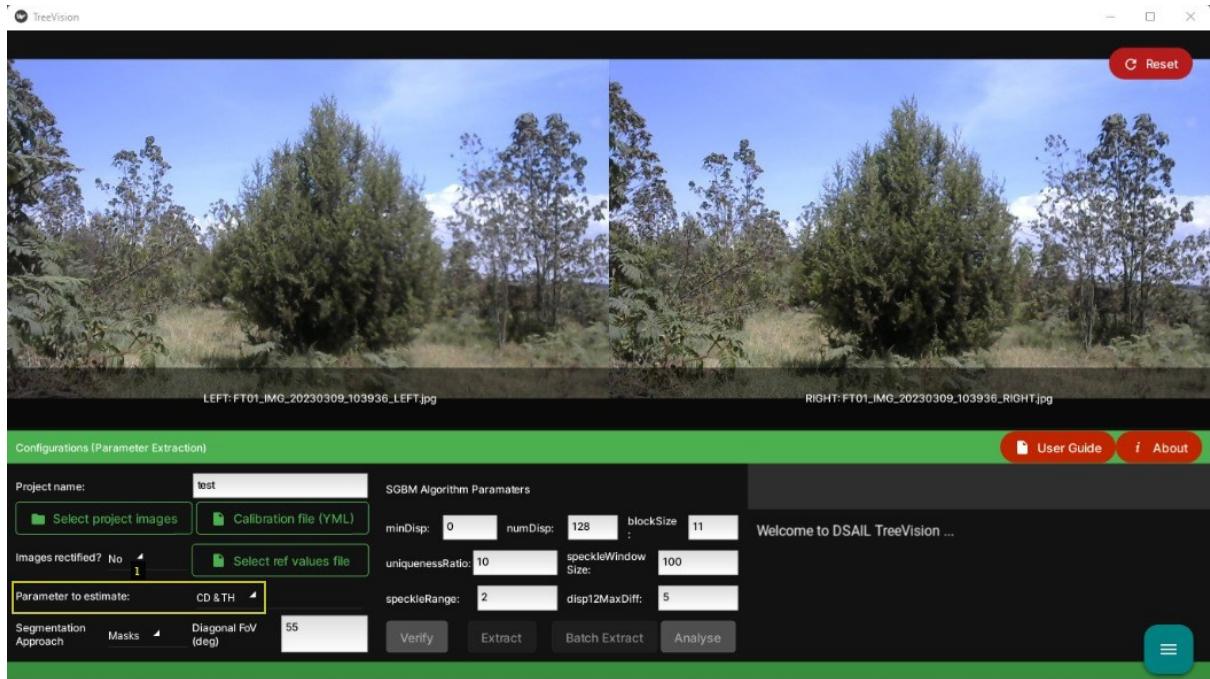
- vi. If you would like to compare the extracted parameters to their ground truth values, select the file of ground truth values by clicking the **Select ref values file** button then navigate to the location of the file and select it.



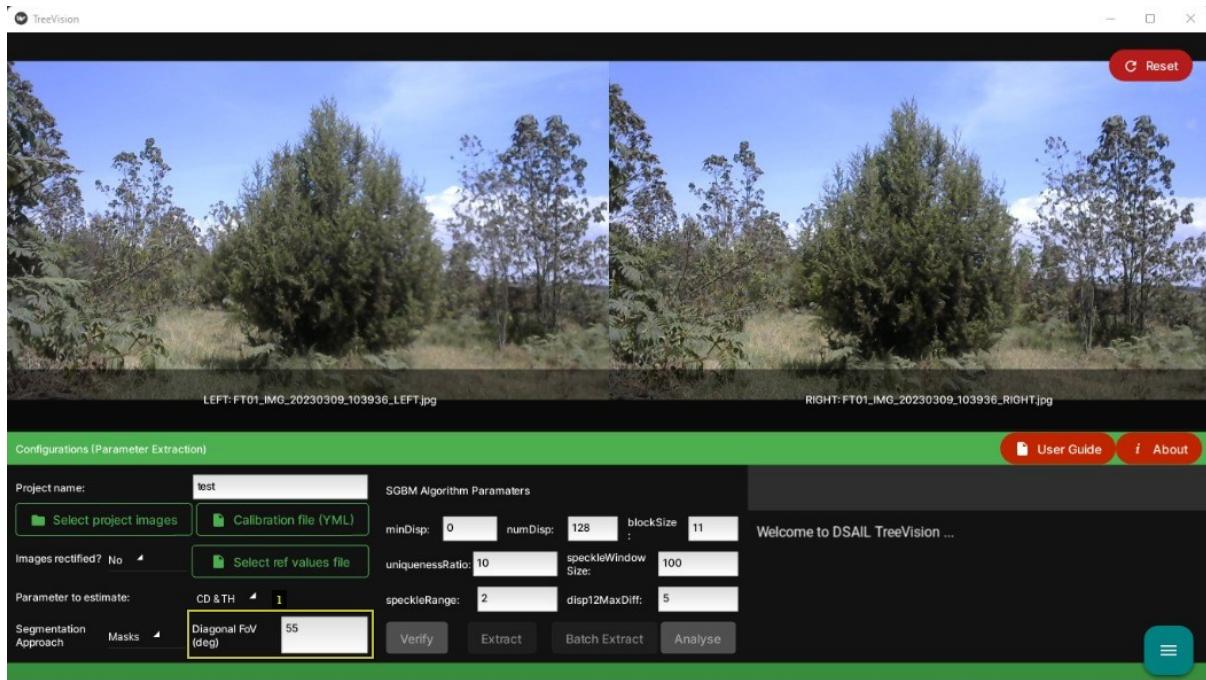
- vii. To choose the parameter you wish to extract, click on the **Parameter to estimate** dropdown list, and choose either “CD & TH” or “DBH”. The first one refers to the crown diameter (CD) and tree height (TH), both of which are extracted simultaneously from an image of a full tree. The second refers to the diameter at breast height (DBH) and is extracted from images of tree trunks.



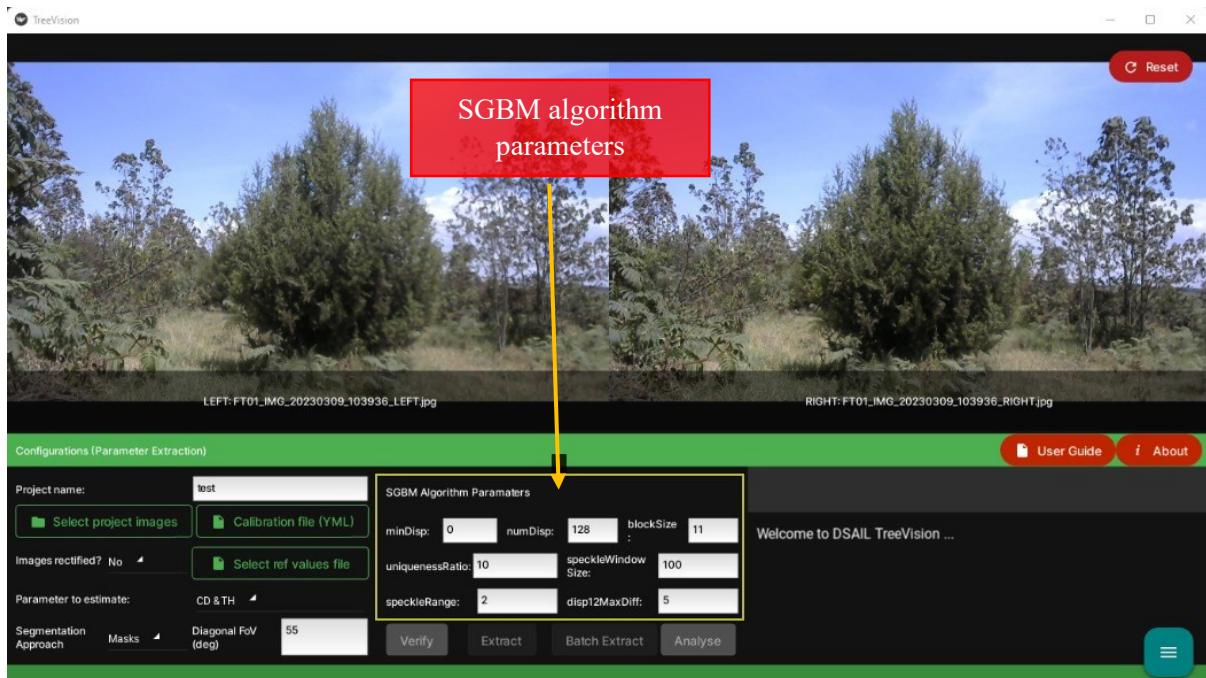
- viii. The image segmentation currently implemented in *DSAIL-TreeVision* is the use of pre-obtained image masks and is the only available item on the **Segmentation Approach** dropdown list. Leave it as it is.



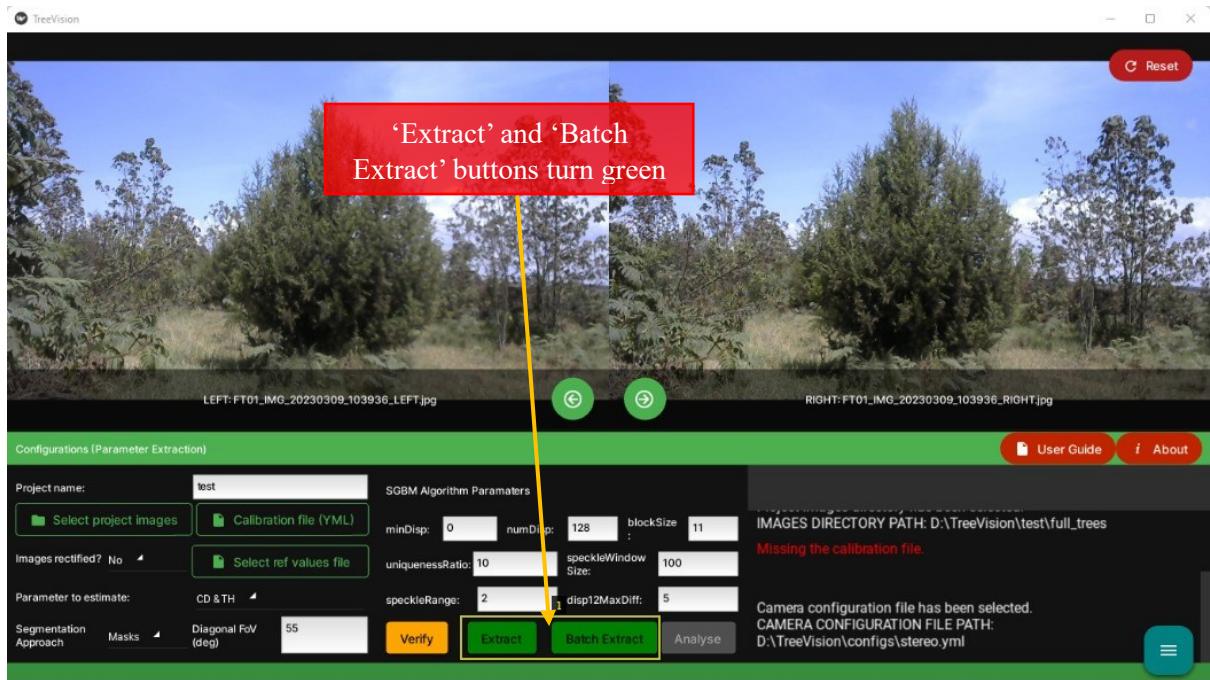
- ix. Provide your stereo camera's diagonal field of view in degrees by filling in the **Diagonal FoV (deg)** text field. Check with your camera manufacturer to find this value.



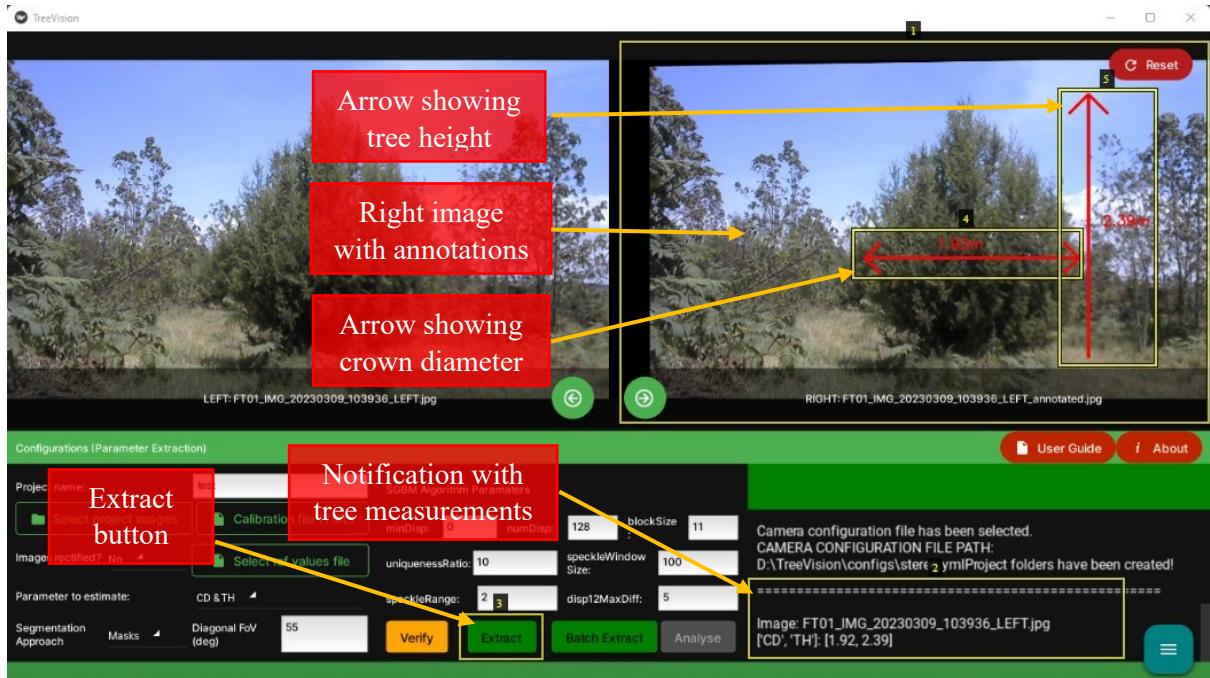
- x. Provide the **SGBM Algorithm Parameters** used for computing the depth map needed to estimate the tree measurements. Users are encouraged to use the default values and to only tweak them if they are sure they are sure of what they are doing. For the meaning of each individual parameter, visit the [OpenCV documentation of the SGBM algorithm](#).



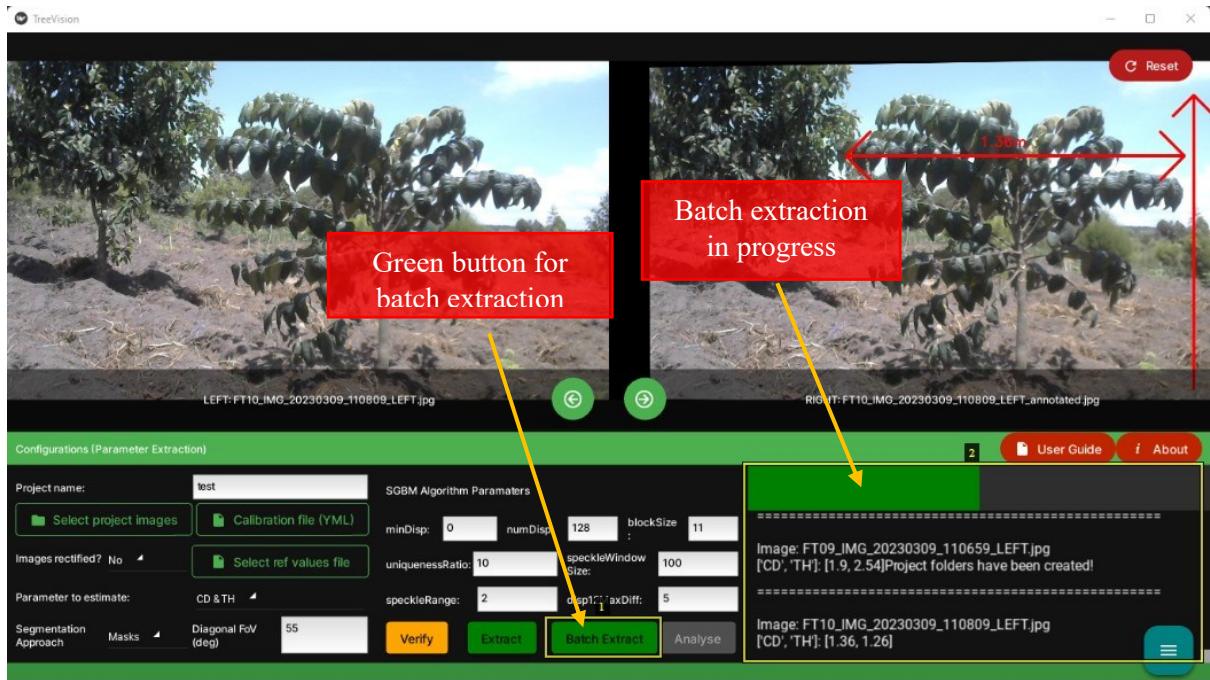
- xi. With the inputs in place, now click on the orange **Verify** button to check that all the user inputs are valid. If you entered everything correctly, the green **Extract** and **Batch Extract** buttons should turn green. Otherwise, you will be notified of any errors by red text in the logging section.



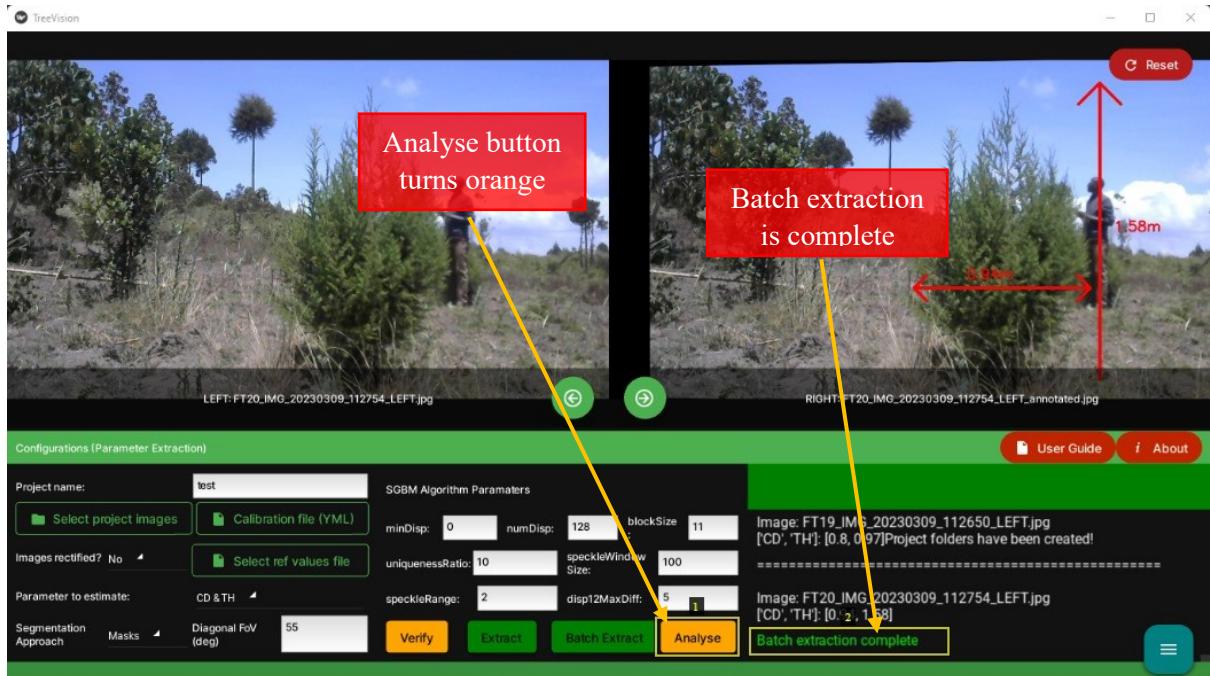
- xii. To extract the parameters from a single image pair, scroll to the image of interest and click on the green **Extract** button and then view the results displayed in the logging section.



- xiii. To extract parameters from all the image pairs in the selected folder, click on the green **Batch Extract** button and wait for the process to complete.

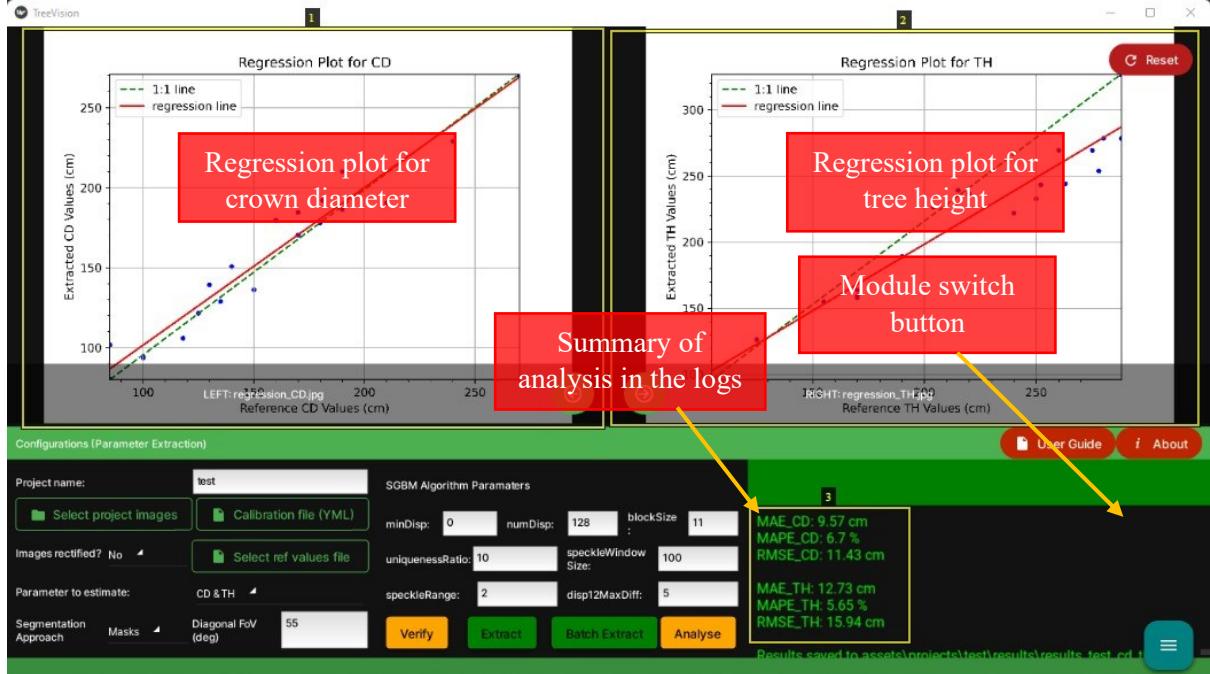


The extraction will be complete once you see a notification “Batch extraction complete” in the logging section and the **Analyse** button turns orange.

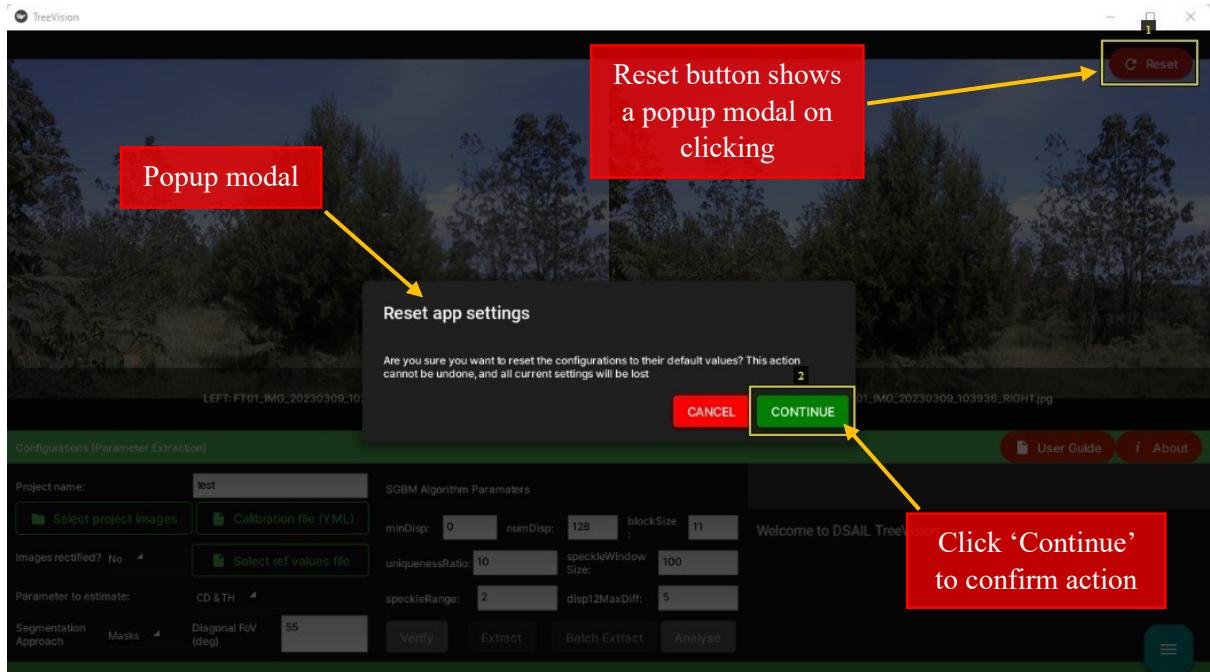


- xiv. If you wish to compare the extracted parameters to their ground truth values, click on the **Analyse** button, and wait for the analysis to complete. You must have uploaded the **reference parameters file** in step vi before clicking the Analyse button. The analysis will be complete when regression plots are displayed on the image widgets of the user interface.

For details about the required format of the file of ground truth values, section Appendix I.

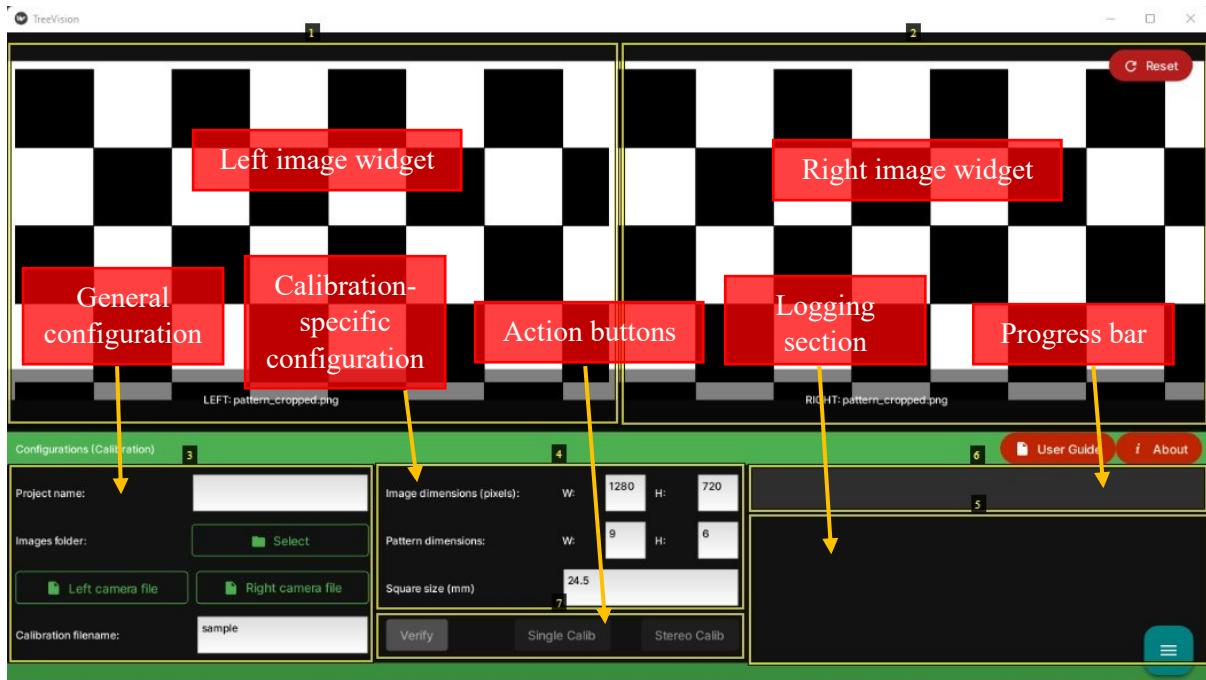


- xv. To restore all the default settings of the Extract module, click on the Reset button and confirm the action.



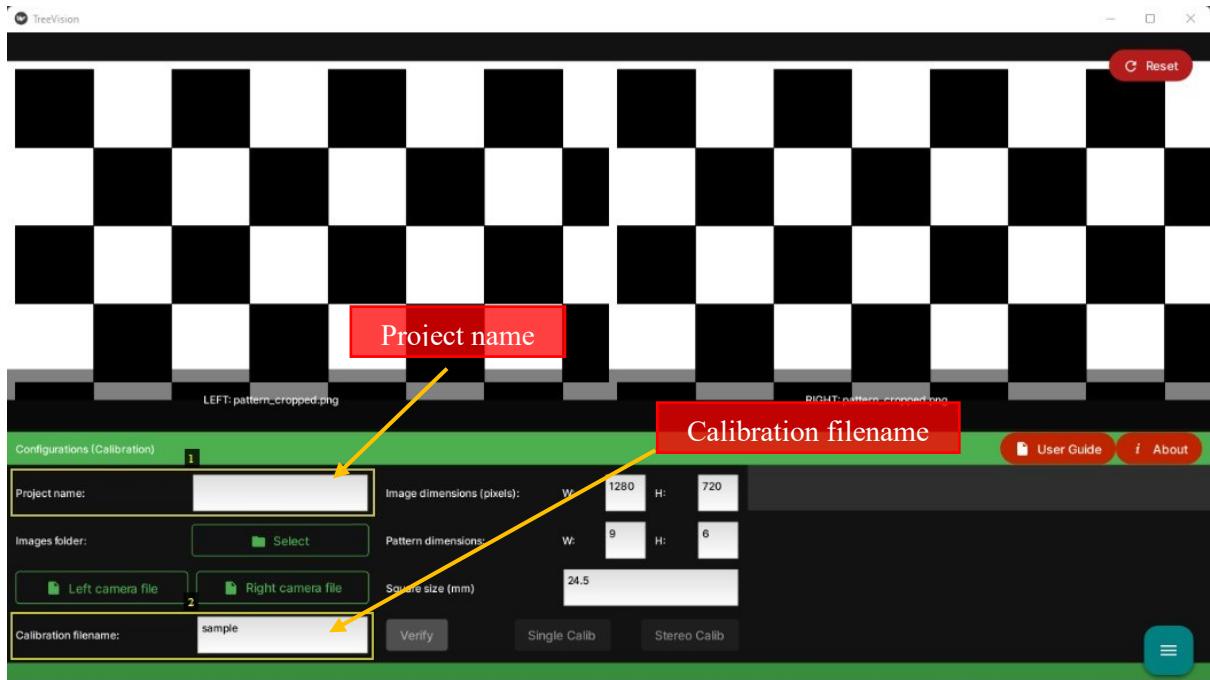
## 5.2 DSAIL-TreeVision Calibrate Module

The user can calibrate their individual cameras or stereo cameras using the *DSAIL-TreeVision* Calibrate Module. Figure 2 shows the user interface of this module.

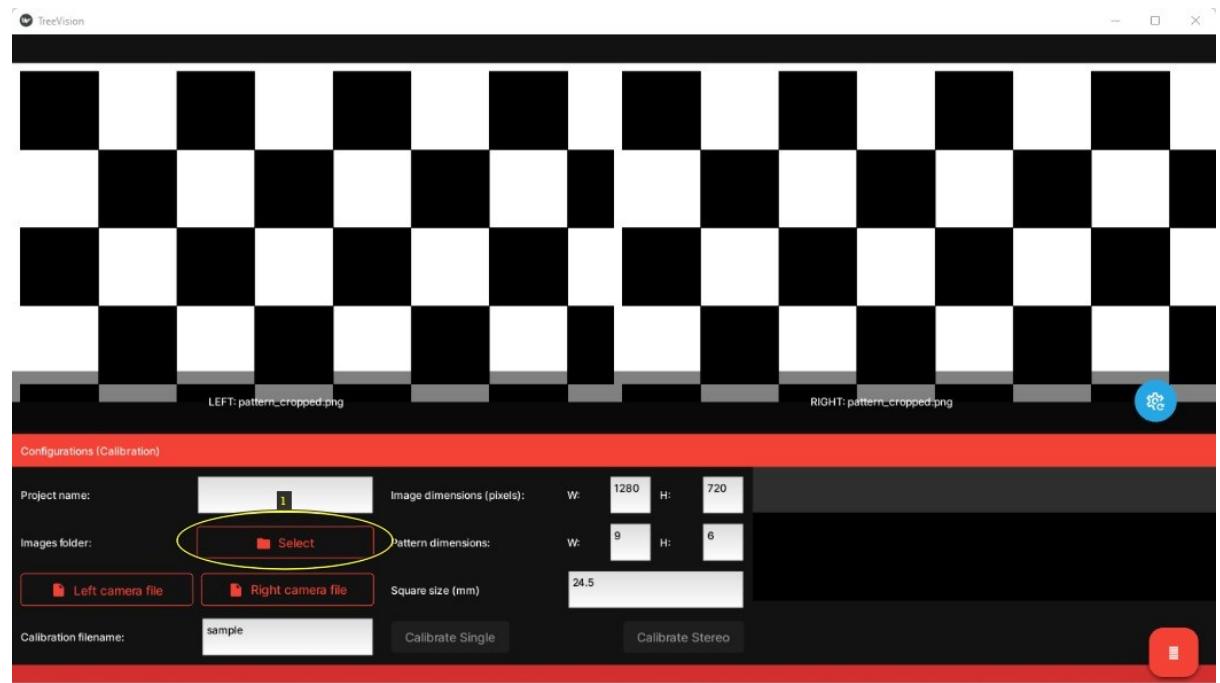


To calibrate a camera using this module, follow the following steps:

- i. Provide the **Project name** and **Calibration filename** by typing them in. The project name is the name of the project with which the calibration being performed is associated, and a folder will be created for each project. Often, before beginning to capture images for a project, you may need to perform the calibration. The calibration filename is the name of the file where the camera's calibration parameters will be saved, and the file will be saved inside the “{Project name}” folder. The filename should have no white spaces within it provided and should not include a file extension as all files are saved as YAML files. If you repeat a calibration and provide the same project name and calibration filename, the calibration file will be overwritten.

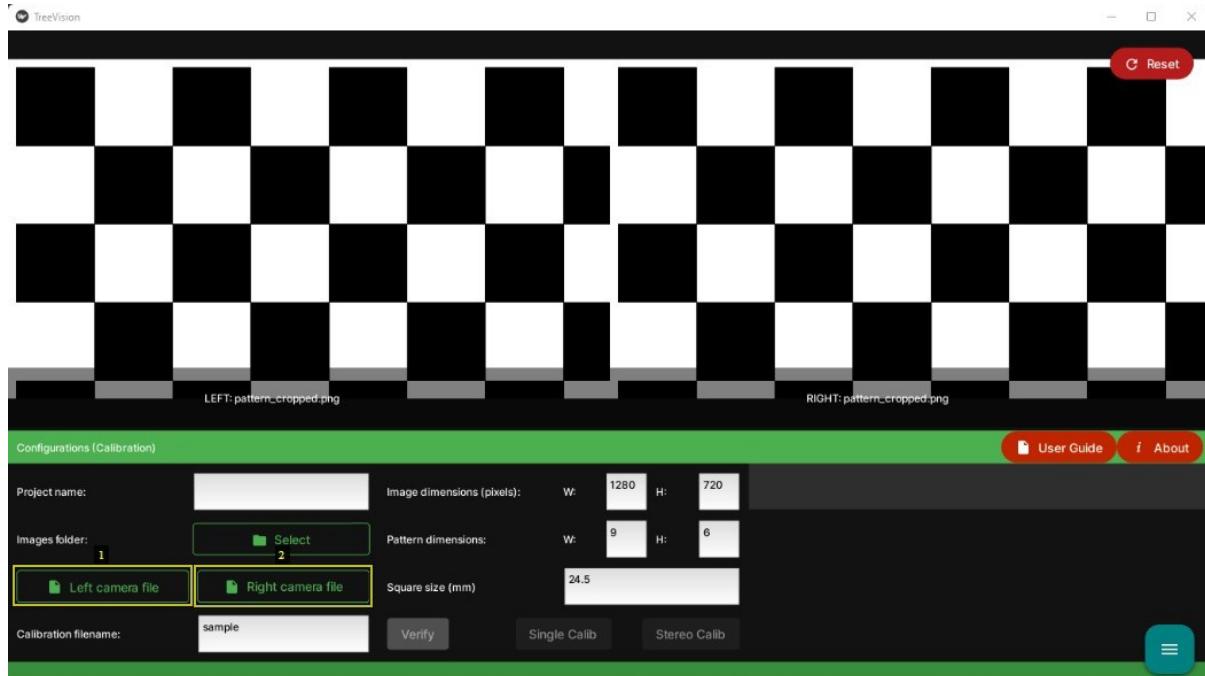


- Click on the button adjacent to the **Images folder** and navigate to the directory where your calibration images are stored.

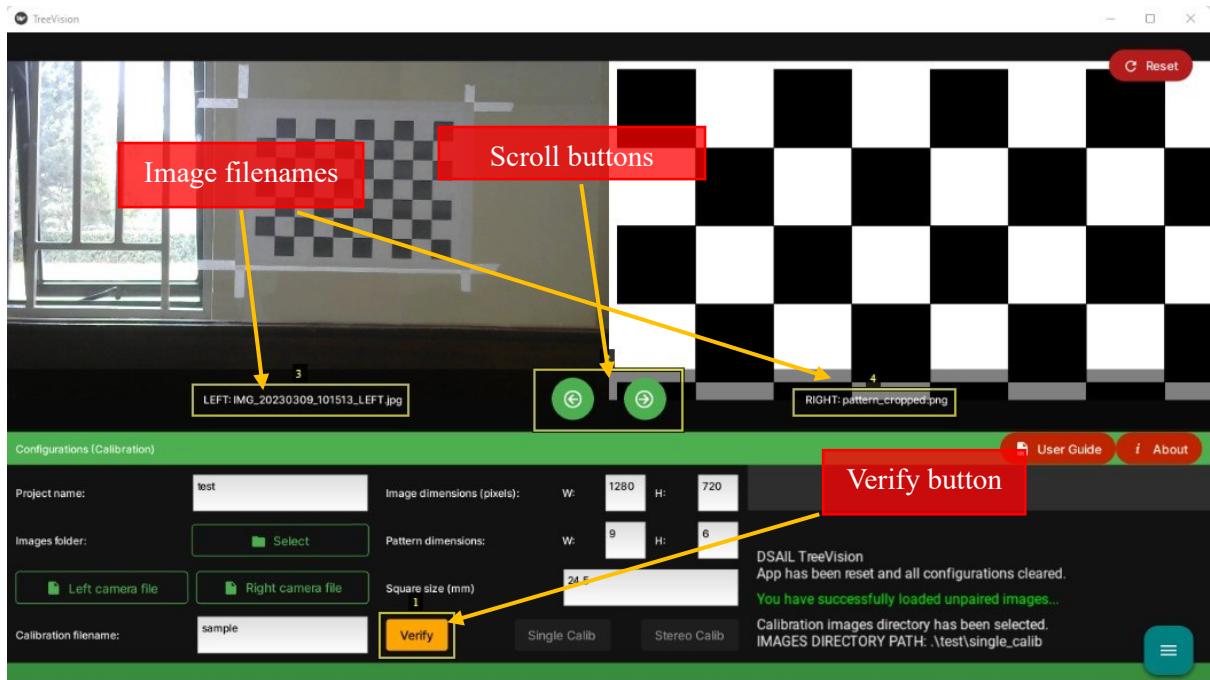


If calibrating a stereo camera, ensure that all left and right image pairs are stored in the same folder. If calibrating a single camera that may be part of a stereo camera assembly, ensure that the containing folder does not have both left and right images. Instead, you may place the left and right images in separate folders. The filenames of the images should follow the following patterns:

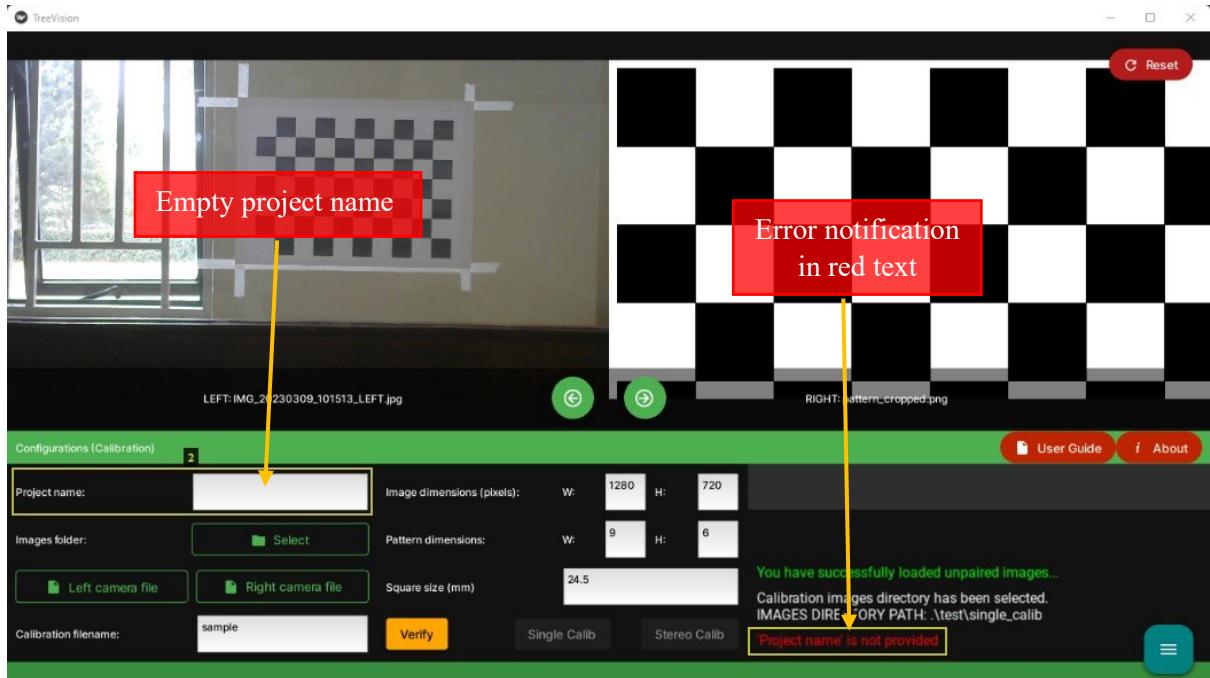
- Left images filenames should follow one of the patterns “\***LEFT**\*.{ext}” or “\***left**\*.{ext}” where \* represents any number of any alphanumeric characters and {ext} represents the file extension which may be either “jpg” or “png”.
  - Right images filenames should follow one of the patterns “\***RIGHT**\*.{ext}” or “\***right**\*.{ext}” where \* represents any number of any alphanumeric characters and {ext} represents the file extension which may be either “jpg” or “png”.
  - The filenames for unpaired images used for single camera calibration should follow the pattern “\*.{ext}” where \* represents any number of any alphanumeric characters and {ext} represents the file extension which may be either “jpg” or “png”.
- iii. If calibrating a stereo camera, provide the left and right camera calibration files by clicking the **Left camera file** and **Right camera file** buttons and navigating to the respective files. If your cameras are identical and have the same calibration parameters, you can select the same file in both instances.



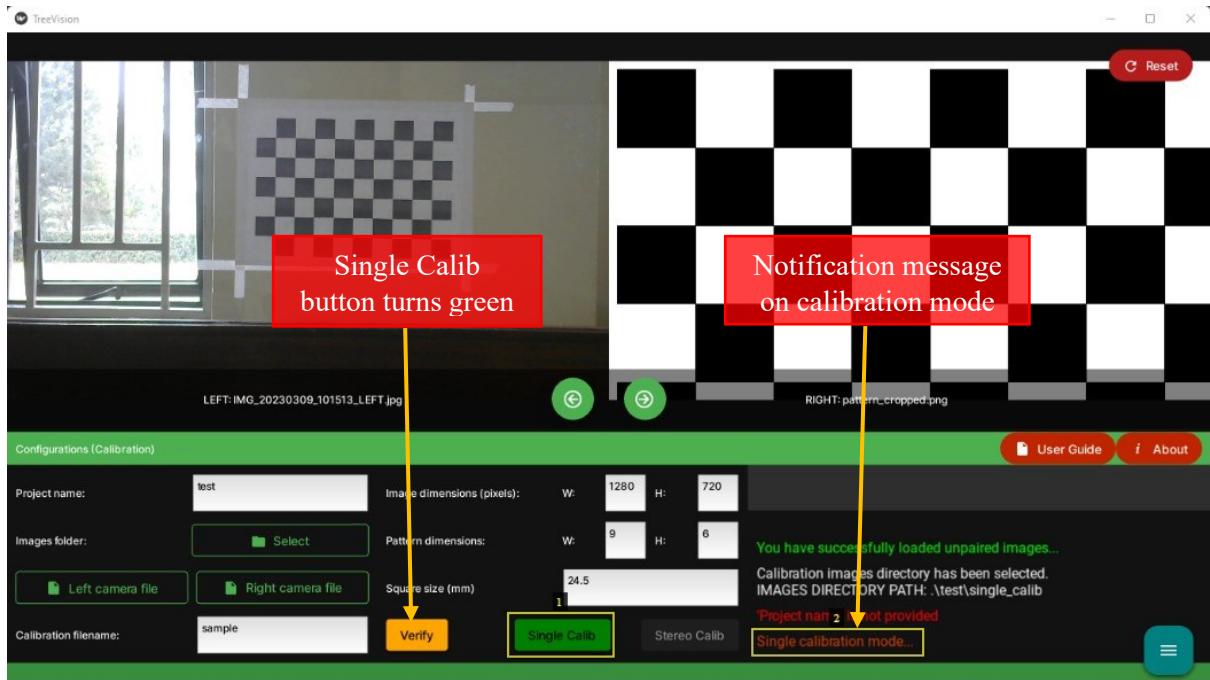
Once you load either single or paired images, first pair (or image) in the sequence will now be displayed on the user interface together with their filenames near the bottom of each image widget. There will also appear **Scroll buttons** for scrolling left and right through the sequence of images. By loading the images, the **Verify** button also turns orange to allow the user to check that all their inputs are valid.



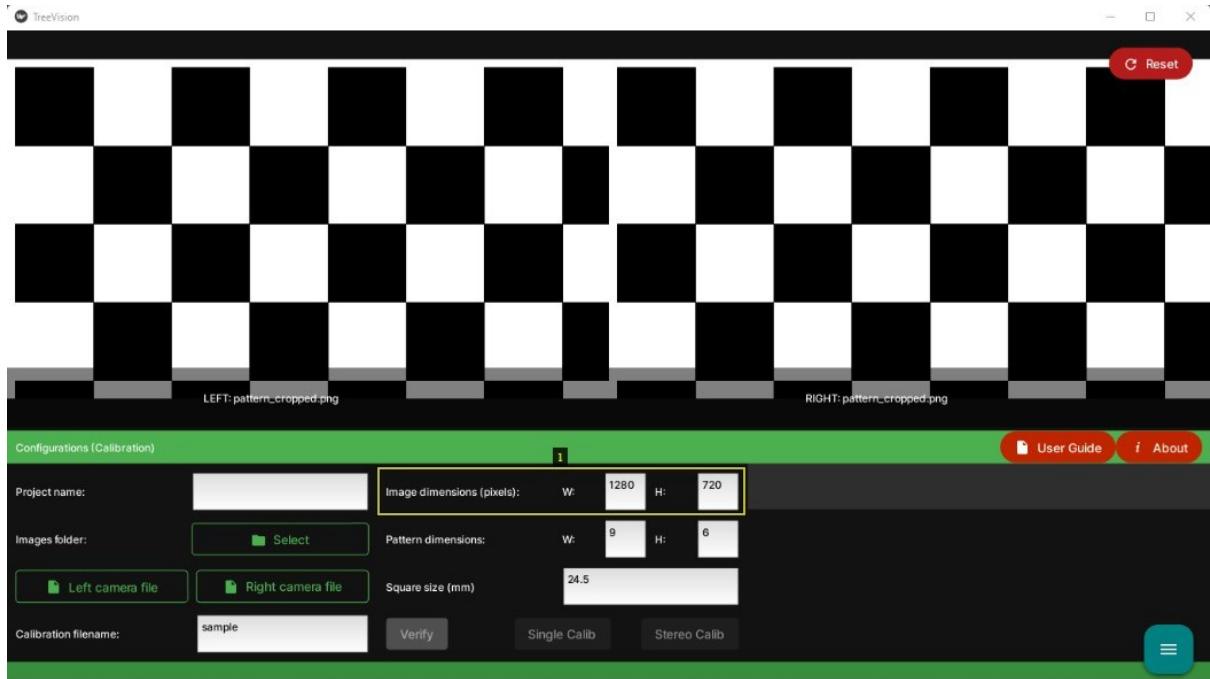
If there are missing or invalid user inputs, clicking the **Verify** button will lead to error messages being displayed in the logging section in red text.



If all the user inputs are valid, clicking the **Verify** button will cause either **Single Calib** button or the **Stereo Calib** button to turn green depending on whether unpaired images or stereo images were loaded respectively. There will also be a corresponding notification message in the logging section informing the user the calibration mode they are entering.

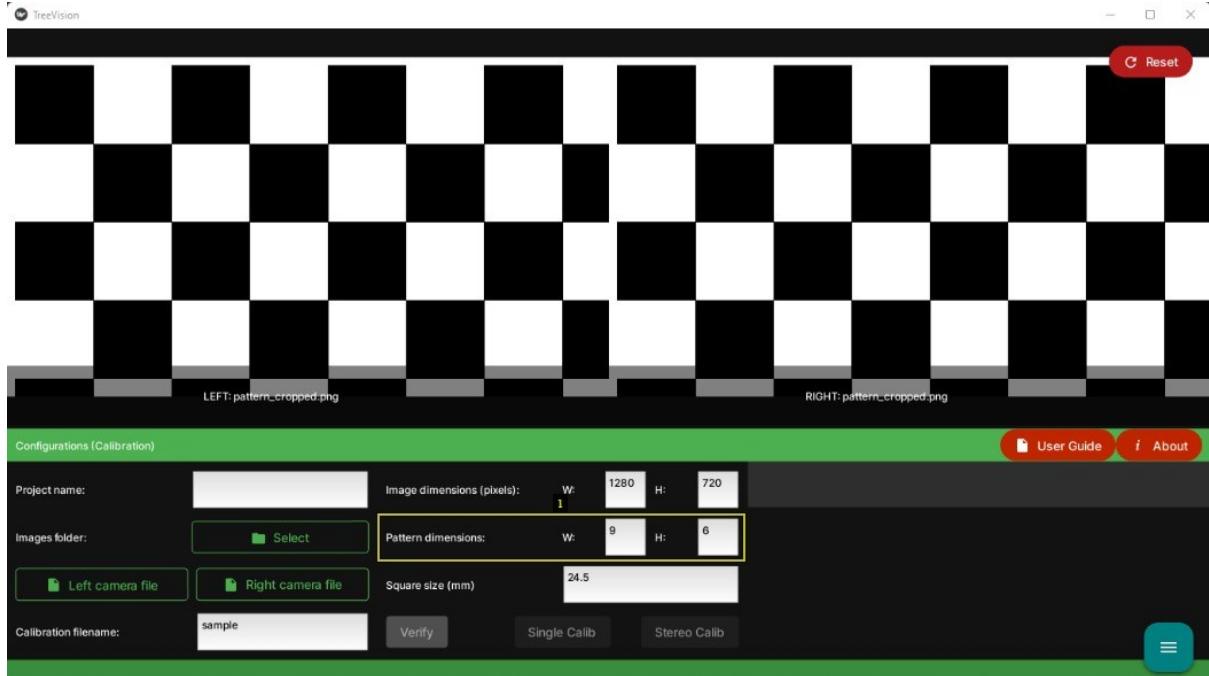


- iv. Enter the image dimensions based on the camera resolution in the text fields adjacent to the **Image dimensions (pixels)** setting. **W** is the image width in pixels and **H** the height in pixels.

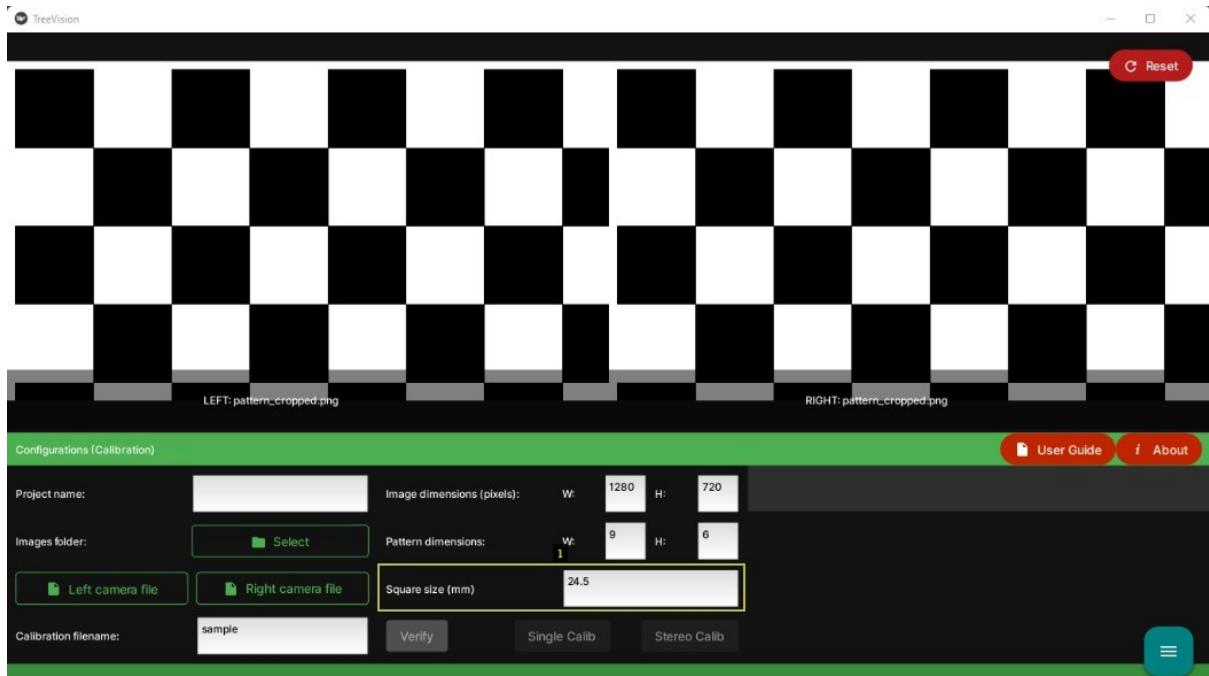


- v. Enter the checkerboard calibration pattern dimensions in the text fields adjacent to the Pattern dimensions setting. **W** is the width of the pattern and **H** is its height. For clarification, the dimensions refer to the number of internal corners along the length and breadth of the checkerboard pattern. For example, in a pattern having 10 squares and 7

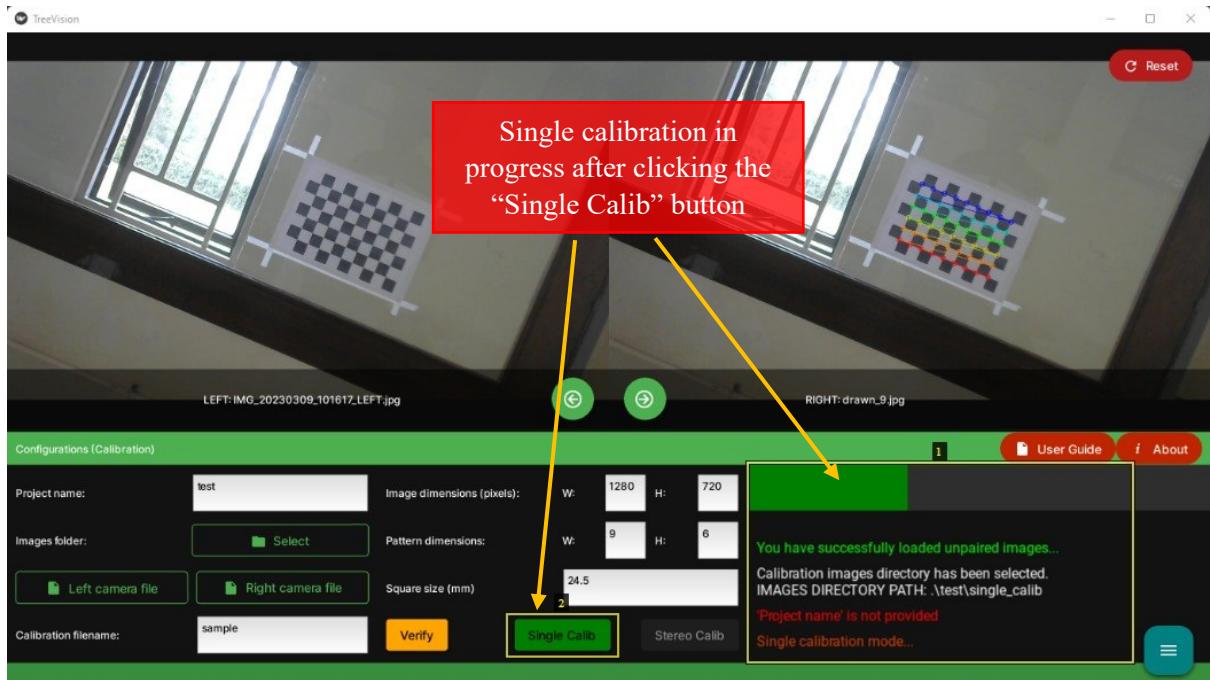
squares along its length and breadth respectively (such as [this one provided by OpenCV](#)), the dimensions will be W=9 and H=6.



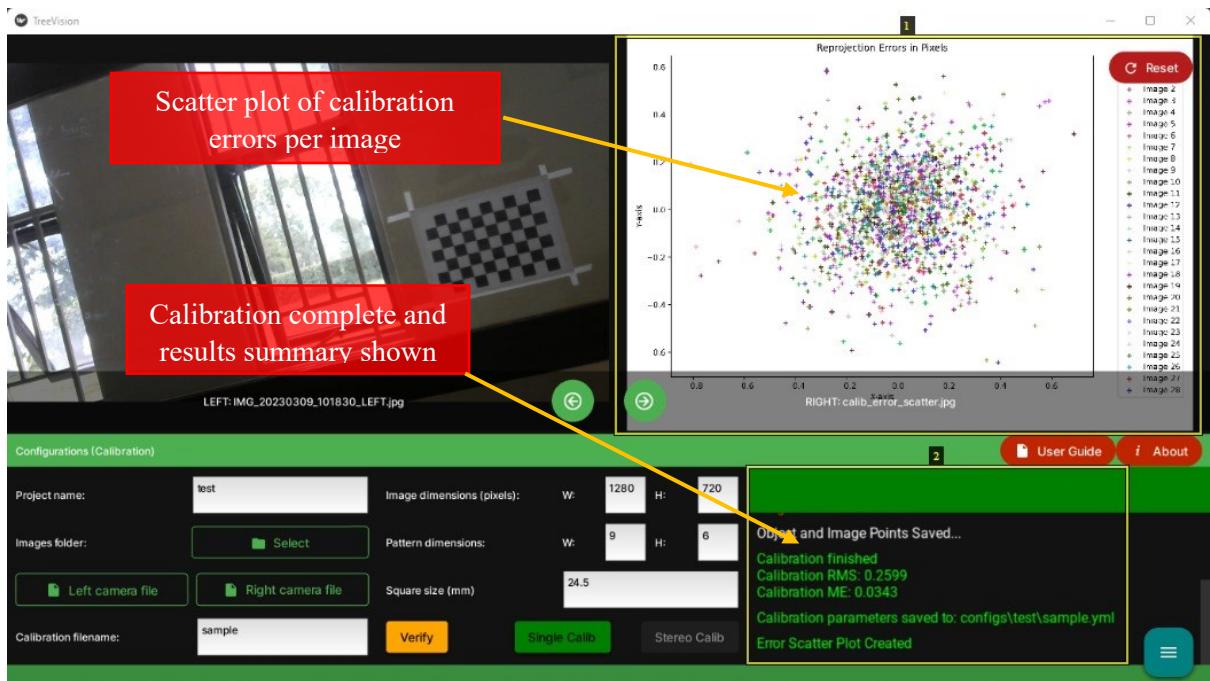
- vi. Enter the square size in mm in the **Square size (mm)** setting. To find this value, use a well-graduated ruler or vernier calliper to measure the size of a square in your printed pattern.



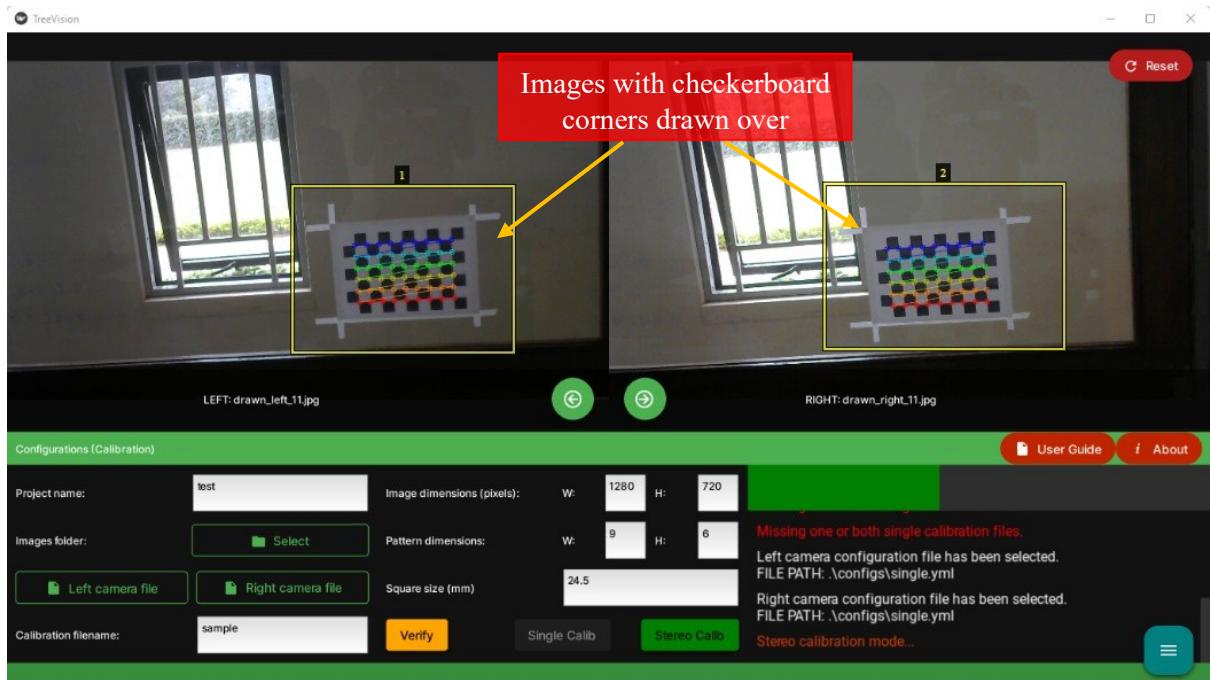
- vii. If you are calibrating a single camera, click on the green **Calibrate Single** button to begin your calibration and wait for the process to complete.



The process is complete when you see the text message “**Calibration finished**” in the logging section and the image widgets display scatter plots of the calibration errors.



- viii. If you are calibrating a stereo camera, click on the green Calibrate Stereo button to begin your calibration and wait for the process to complete. As the tool loops through each calibration image pair, the positions of the checkerboard corners are drawn over by OpenCV and displayed on the user interface. The process is complete when you see the text message “**Stereo calibration complete**” in the logging section.

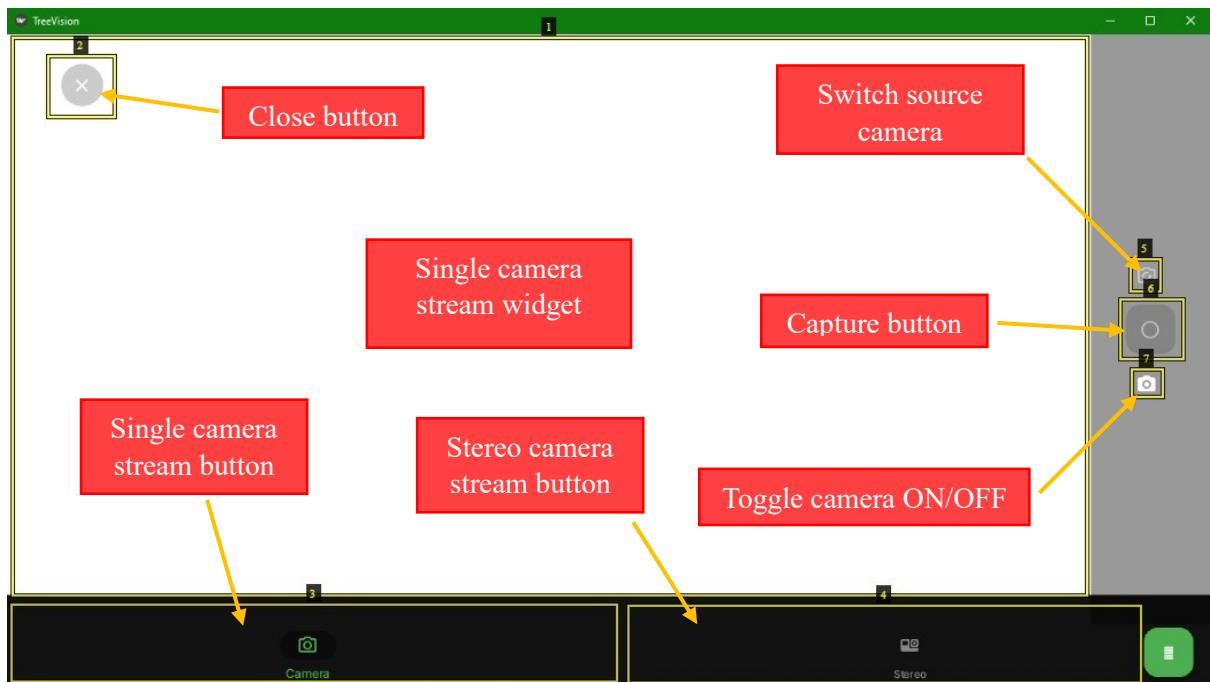


- ix. To view your calibration files, navigate to the “`configs/{project}`” directory ( where `{project}` is the project name you provided) in your computer’s file system and you should see all your calibration files with the “`.yml`” extension.

### 5.3 DSAIL-TreeVision Capture Module

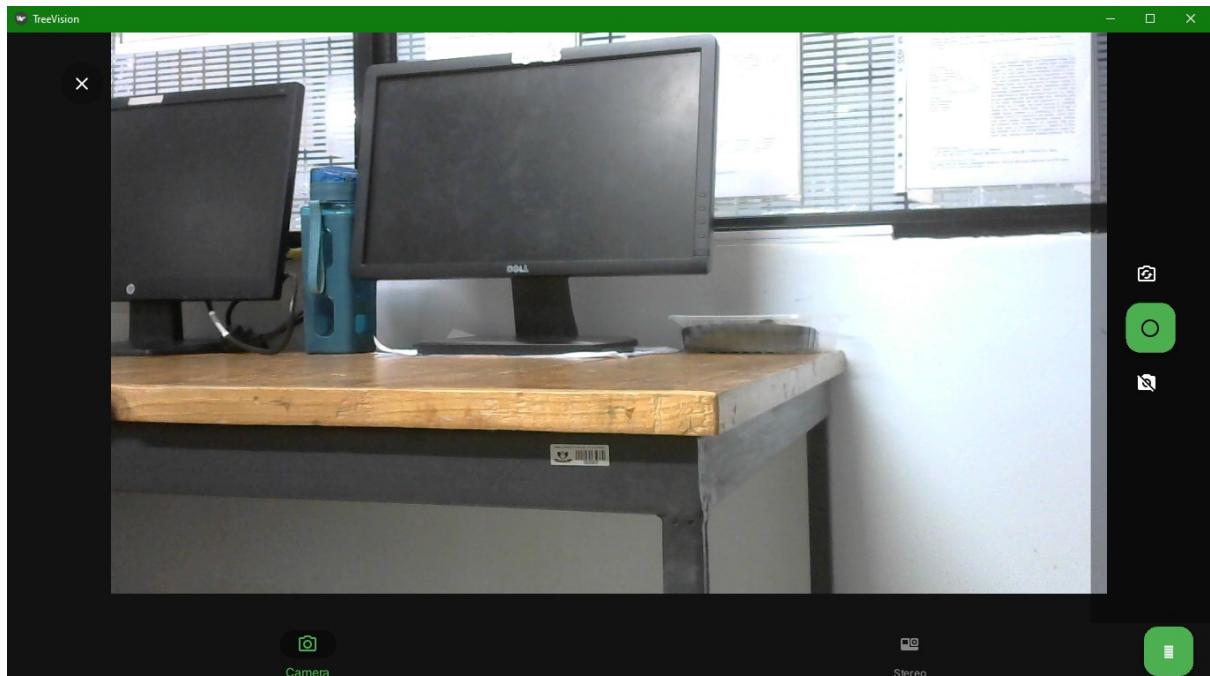
The *DSAIL-TreeVision* Capture Module provides a platform for capturing both single and stereoscopic images. The OpenCV library is used to interface the software and the camera. This module has been tested with Logitech C270 USB cameras. Other cameras that work with OpenCV may be used but the code may need modifications. You can check out the sample images in the “`test/trunks`” and “`test/full_trees`” folders in *DSAIL-TreeVision*’s root directory for sample images.

- i. When the user switches to this module, *DSAIL-TreeVision* is in the single camera stream mode with the camera turned off. The user interface of the module in this state is shown below.

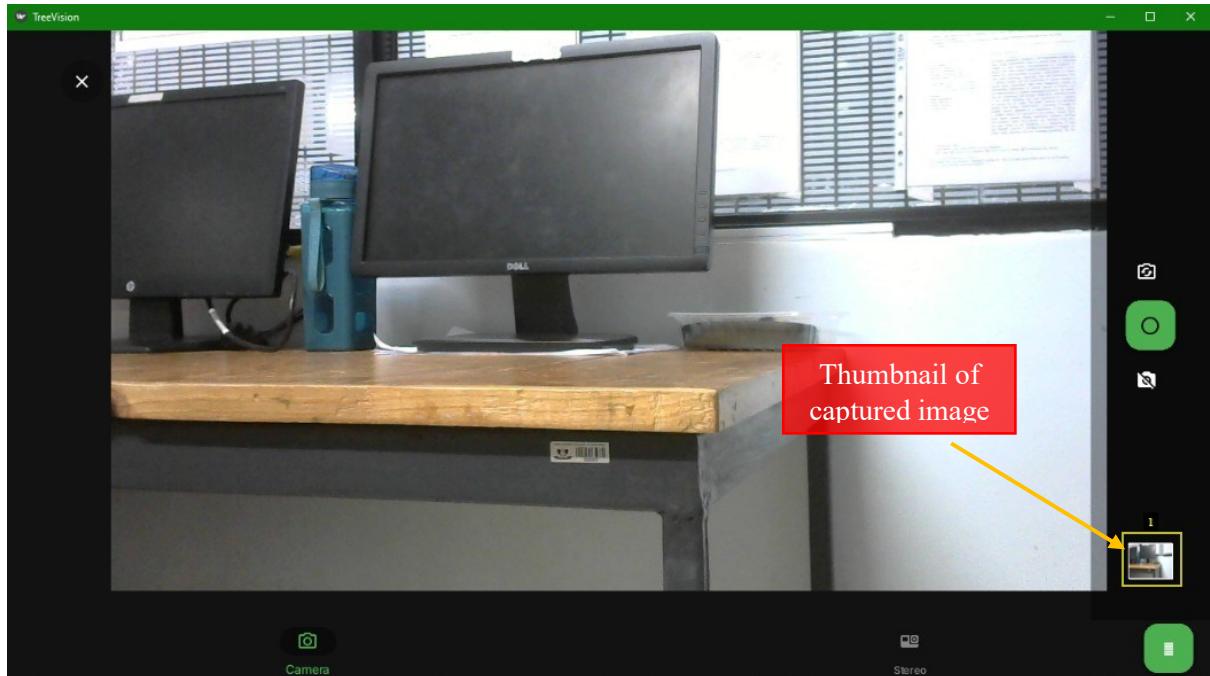


The **close button** exits the application and closes the window. If there are more than one camera connected to the computer, the **switch source camera button** allows the user to stream from a different camera. To capture and store an image, the user taps on the **capture button**. The camera can be toggled on or off using the **Toggle camera ON/OFF button**. To switch between single camera and stereo camera modes, the user taps the corresponding buttons at the bottom of the application window.

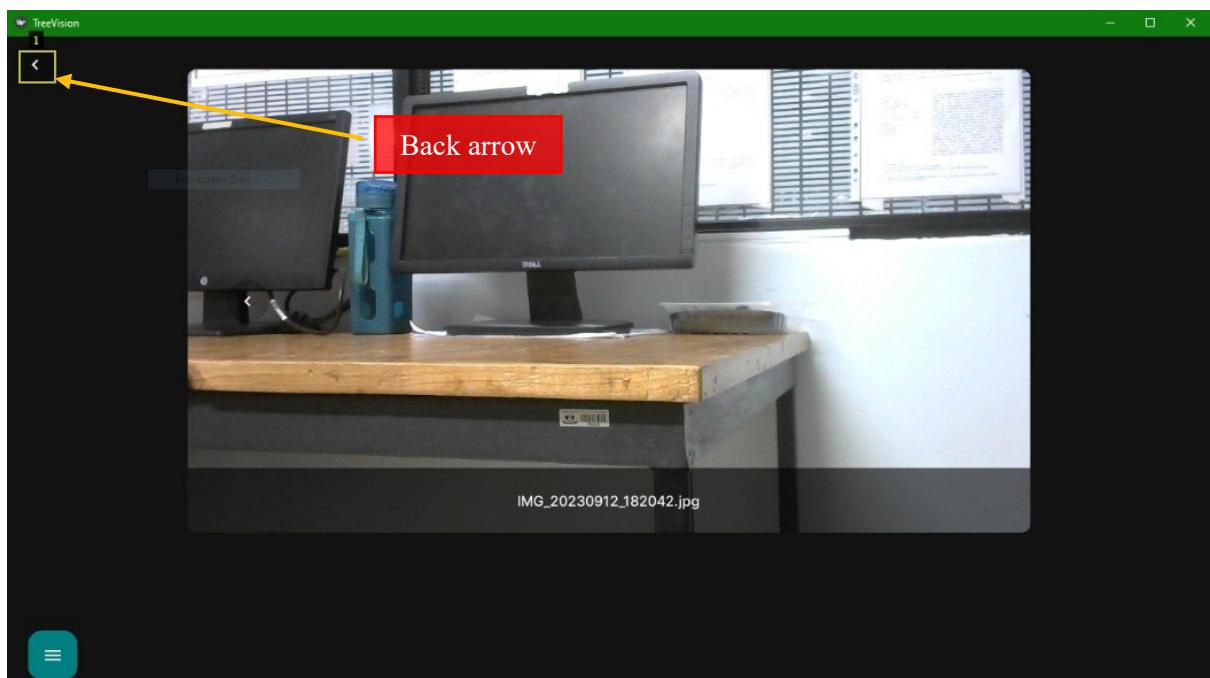
- ii. Here is a screenshot showing a single camera stream displayed on the camera stream widget when the camera is turned on.



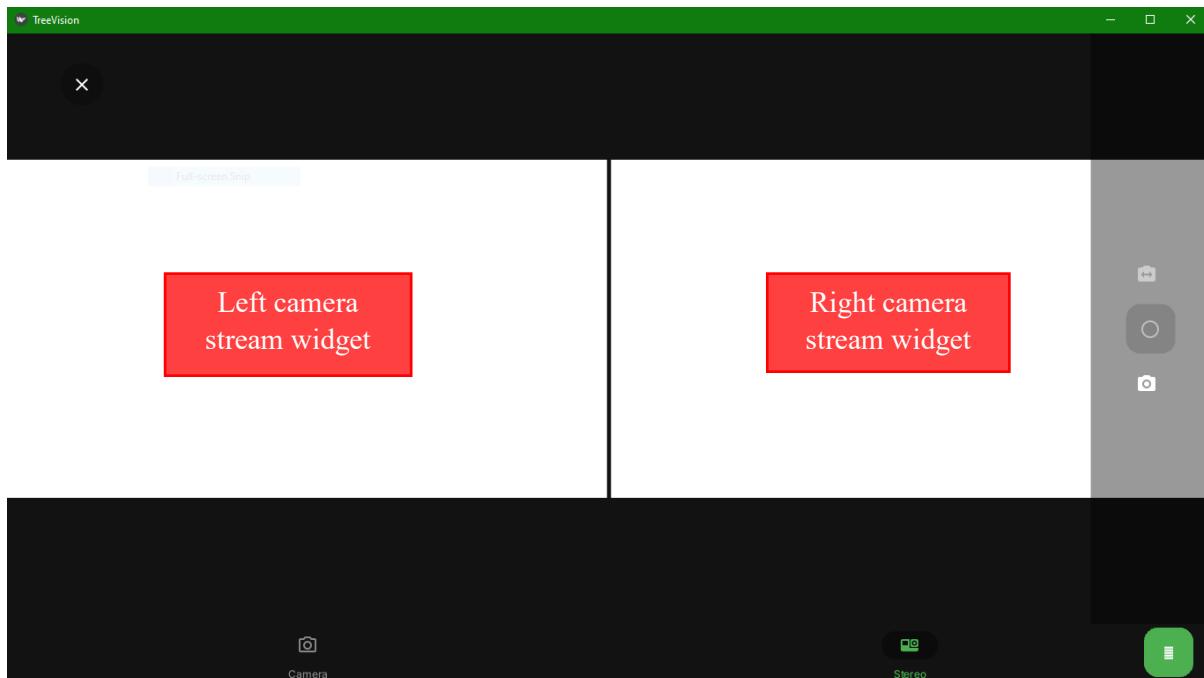
- iii. Once the user captures an image using the capture button, a thumbnail of the captured image will be displayed at the bottom right of the application window. Notice the highlighted thumbnail at the bottom left of the following figure.



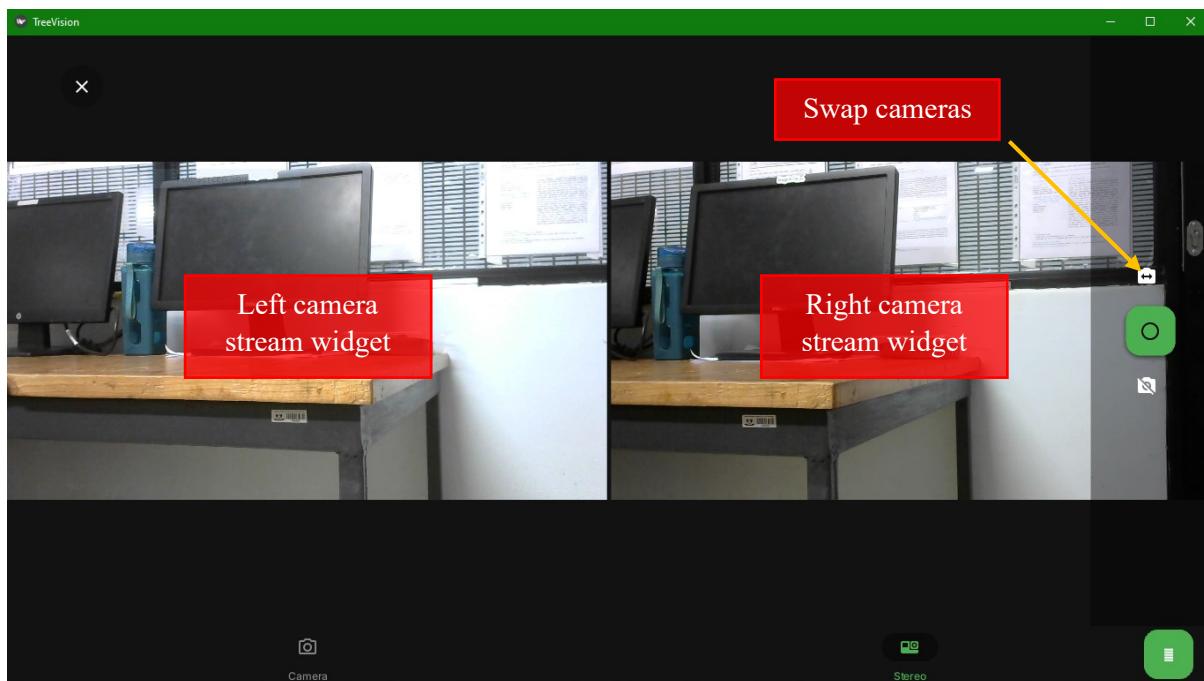
- iv. To view the image just captured , tap on the thumbnail. On the viewing screen, there is an arrow for navigating back to the camera stream.



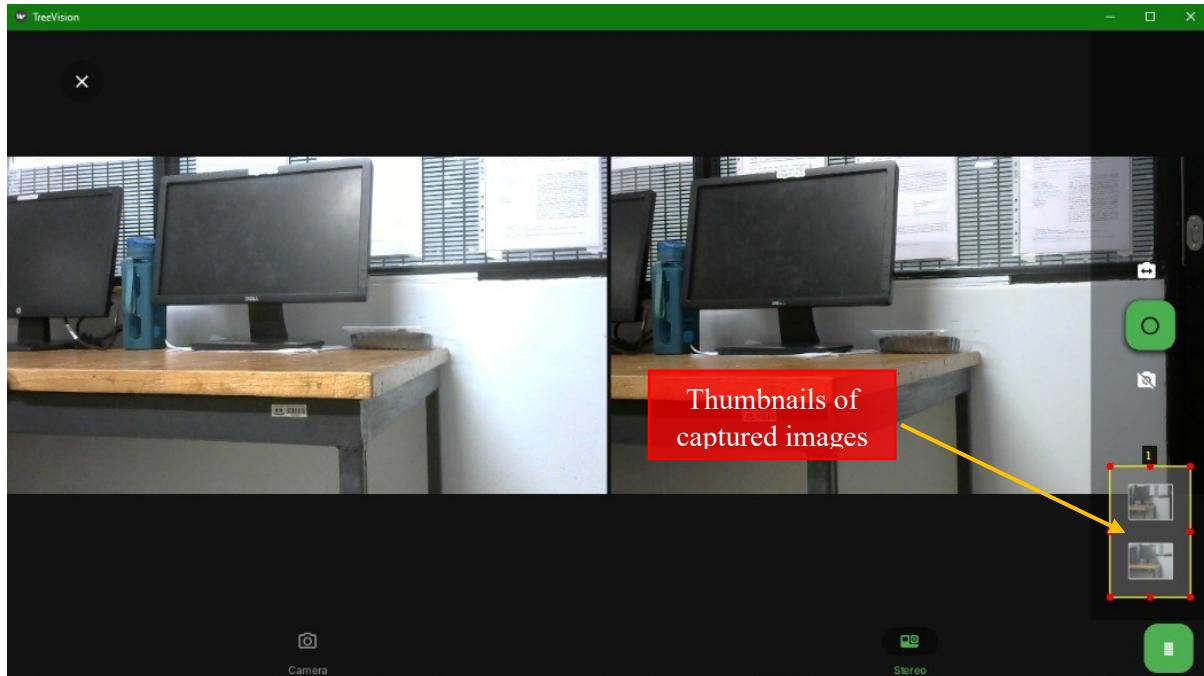
- v. To switch to the stereo camera stream mode, tap on the Stereo button at the bottom of the screen. If the cameras are turned off, the user interface will look as shown below.



- vi. To turn on the cameras, click on the Toggle cameras ON/OFF button. The left and right camera streams will now be displayed in their individual widgets as shown below. The **Swap cameras button** shown in the figure is used to swap the left and right camera streams. It makes the left camera stream the right camera stream and vice versa. Sometimes, it may be necessary to do the swap if the camera indices are mixed up.



- vii. When the capture button is pressed in the stereo mode, *DSAIL-TreeVision* captures and saves the left and right images simultaneously. Thumbnails of the captured pair are then displayed at the bottom left of the application window as shown below.



## 6 Appendix I

### 6.1 Ground Truth Values File Format

The file containing the ground truth values for the diameter at breast height (DBH), crown diameter (CD) and the tree height (TH) must conform to the format provided here for the analysis to be possible. The values for CD & TH should be contained in a single CSV file having 3 columns as shown in the table below. The column names should exactly as they appear in this table. The units of the parameters should be metres (m).

Filename	Ref_CD	Ref_TH
FT01_IMG_20230309_103936_LEFT.jpg	181	215
FT02_IMG_20230309_104643_LEFT.jpg	85	155

The values for DBH should be in separate CSV file having 2 columns as shown in the following table. Again, the column names should be as they appear in this table and the units should be in centimetres (cm). Not metres (m).

Filename	Ref_DBH
T01_IMG_20230531_114915_LEFT.jpg	30.56
T02_IMG_20230531_115337_LEFT.jpg	24.19

In the case where the images were not captured using *DSAIL-TreeVision*, the naming convention of the filenames **MUST** be such that the filenames for each left-right pair have the strings “left” and “right” respectively within them. The individual filenames for each image. This naming convention helps *DSAIL-TreeVision* separate the left and right images correctly. For ease of reference, the filename to be included in the CSV file is the **left image** of image pair containing the tree of interest.

## 6.2 Camera Calibration File Contents

To be able to successfully extract tree parameters from stereoscopic images using *DSAIL-TreeVision*, the user must provide a valid camera calibration file. For the case where the supplied images are not rectified, a valid camera calibration file **MUST** have all the 10 matrices described below:

- K1 – Camera calibration matrix of the left camera
- D1 – Five-element distortion matrix of the left camera
- K2 – Camera calibration matrix of the right camera
- D2 – Five-element distortion matrix of the right camera
- T – Translation of the right camera relative to the left camera
- R1 – Output rectification transform (rotation matrix) of the left camera
- R2 – Output rectification transform (rotation matrix) of the right camera
- P1 - Output 3x4 projection matrix in the new (rectified) coordinate systems for the left camera
- P2 – Output 3x4 projection matrix in the new (rectified) coordinate systems for the right camera
- Q – Output 4×4 disparity-to-depth mapping matrix

If the user provides already rectified images, the all the matrices except for R1, R2, P1, and P2 will be required. These parameters must be saved in YAML file with the keys being as they appear in above list i.e., K1, D1, etc. You can read more about these matrices in the [OpenCV documentation](#).

## 6.3 Additional Notes on the Results Displayed in the Logging Section

To minimise the use of space available in the logging section while extracting the parameters of each tree from an image pair, the values of the estimated CD and TH are both displayed on a single line in bracket notation. For example, you may see a result such as “[‘CD’, ‘TH’] = [1.98, 2.44]” displayed below a filename such as “FT01\_IMG\_20230309\_103936\_LEFT.jpg”. This result means that from the image pair where the left image is named FT01\_IMG\_20230309\_103936\_LEFT.jpg, the crown diameter (CD) was estimated to be 1.98 m while the tree height (TH) was estimated to be 2.44 m. More concisely,  $CD = 1.98 \text{ m}$  and  $TH = 2.44 \text{ m}$ .