A Step-by-step User Guide for CropQuant-3D

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The CropQuant-3D Software was developed using the Python GUI package, PyQt5, which allows the software application to be executed on different operating systems such as Windows and Mac OS. The step-by-step user guide detailed below is based on the Windows executable file.

1.1 Access the software

The software is running on Windows 10. Installation requires a user to download the zip file from the GitHub repository (https://github.com/The-Zhou-Lab/LiDAR/releases), unzip the file, and then run the software by double clicking the .exe executable (**Fig. S1.1**).

Figure S1.1 The icon of CropQuant-3D.exe

1.2 Software installation and execution

The initial interface of the software can be seen in **Figure S1.2** (left), where a user can enter input parameters to initiate point clouds processing, 3D trait analysis and results output. On the initial window, default input parameters have been prepopulated for the test LAS files downloadable from the GitHub repository. Users can change the parameters according to their analysis needs. Also, a brief introduction of these analysis steps and associated algorithms can be retrieved by clicking the information icons.

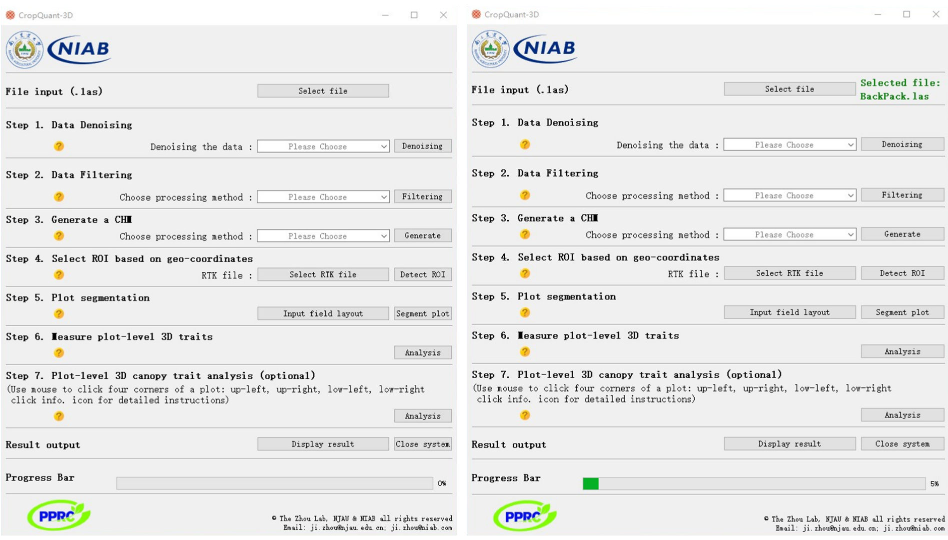

Figure S1.2 An initial window of the software and data input

1.3 Pre-processing point clouds generated by the backpack LiDAR

In the Data Input section, users can click the ‘Select file’ button to select a LiDAR file collected by the backpack LiDAR for 3D trait analysis. This section automatically creates a result folder named with the date and time when the LiDAR file is analysed, where all intermediate results of the analysis workflow will be saved. The analysis workflow of the CropQuant-3D software is divided into 5 parts: data input, data pre-processing, plot segmentation, traits analysis, and data output (**Fig. S1.2**).

1.3.1 Data pre-processing – denoising

In the data pre-processing section, users can perform denoising and filtering on the selected point cloud file (**Fig. S1.3**). To perform denoising, the user needs to input the required parameters N and K (default setting is 50 and 10), after that press the ‘Denoising” button to initiate the denoising algorithm.

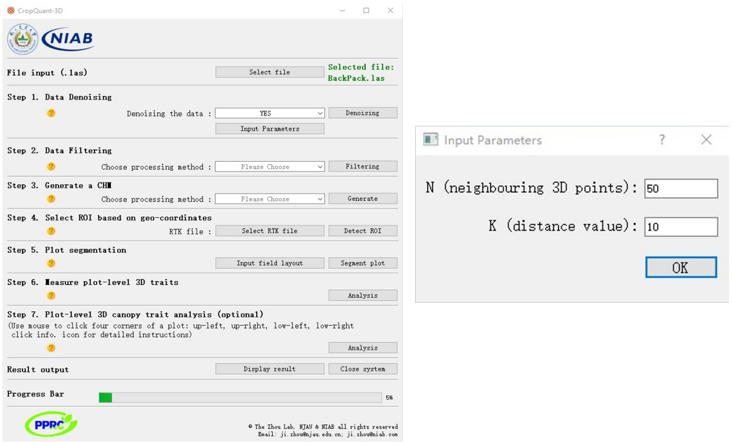

Figure S1.3 Point clouds denoising in *Step 1*

1.3.2 Data pre-processing – filtering

The filtering section is similar to the denoising process (**Fig. S1.4**). The users need to select “Slope based filtering” item from the dropdown list and then define the ‘Radius’ value (the default value is 2). the output of the filtering processing is a new LiDAR point cloud file.

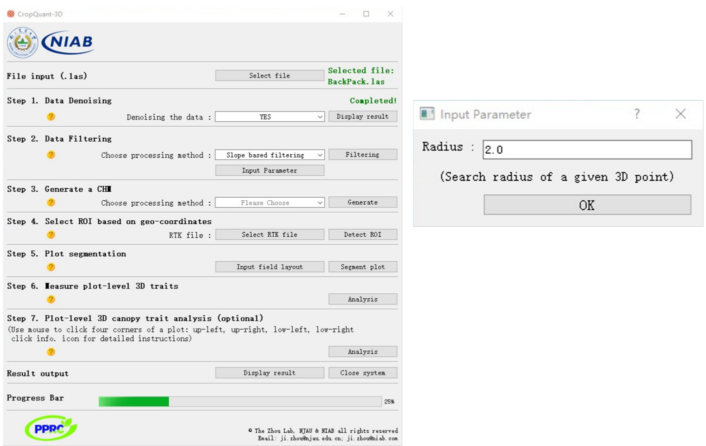

Figure S1.4 Point clouds filtering in *Step 2*

When a section is completed, we can click the ‘Display result’ button to visualise the newly generated point cloud file in 3D (**Fig. S1.5**).

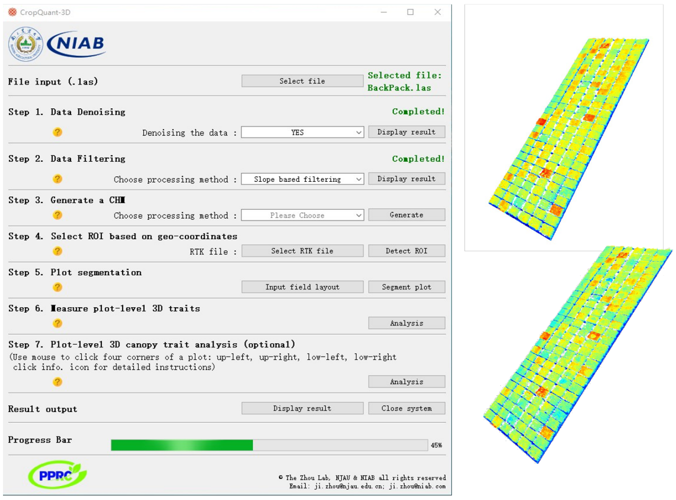

Figure S1.5 Intermediate results visualisation after denoising and filtering

1.3.3 Data pre-processing – generating CHM

To create a 2D CHM file from the processed point clouds in the third step (**Fig. S1.6**, left), users need to select the ‘Tin gridding’ algorithm from the processing method and then enter the input parameter ‘Resolution’ (defaulted to 1, where one stands for the exchange rate is 1 cm per pixel). Users need to press the ‘Generate’ button to create a 2D Canopy Height Model (CHM) image (**Fig. S1.6**, right).

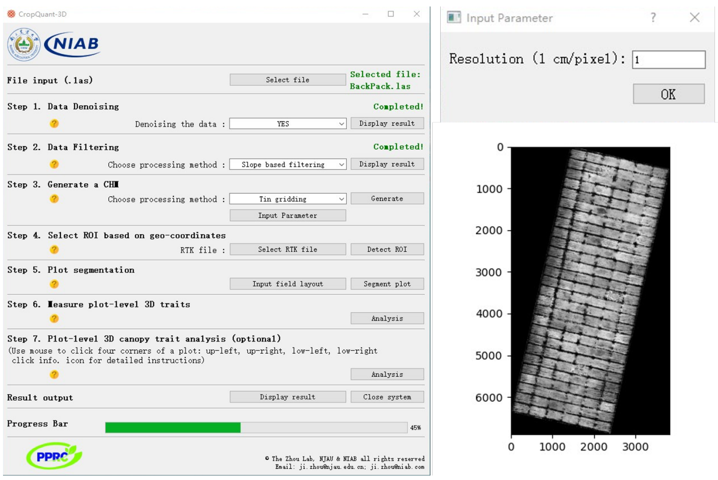

Figure S1.6 Generating a 2D CHM in *Step 3*

1.4 Pre-processing point clouds generated by the UAV-collected point clouds

In the data input section, users can click the ‘Select file’ button to select a UAV-SfM photogrammetry point cloud file for 3D trait analysis. Similar to the backpack LiDAR, this section automatically creates a result folder named with the date and time for this analysis.

1.4.1 Data pre-processing – denoising and filtering

To denoise UAV-generated point clouds, users can perform denoising by inputting the required parameters, after which pressing the 'Denoising' button to initiate the denoising processing. In the filtering section, the users need to select the "Cloth simulation filtering" algorithm. When the filtering is completed, we can click the 'Display result' button to display the generated point cloud file (**Fig. S1.7**, left), which will visualise results in 3D (**Fig. S1.7**, right).

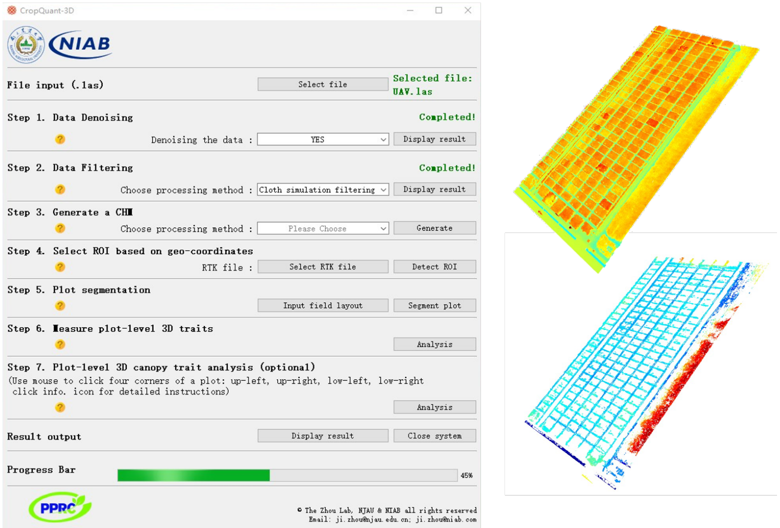

Figure S1.7 The visualisation of UAV-collected point clouds after denoising and filtering

1.4.2 Data pre-processing – generating CHM

To create a 2D CHM file from the point clouds in the third step (**Fig. S1.8**, left), the users need to select 'DSM-DTM' from the processing method and the click the input parameter to select a SHP field (shapefile) to define the geo-coordinates of the experimental field. Users need to press the 'Generate' button to create a 2D Canopy Height Model (CHM) image (**Fig. S1.8**, right).

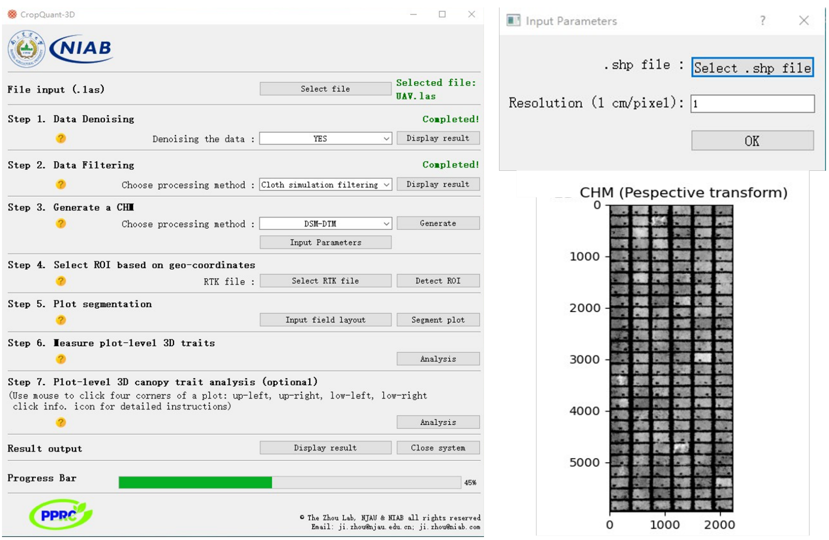

Figure S1.8 The generation of a 2D CHM using the UAV-collected point clouds

1.5 Pre-processing point clouds generated by the gantry LiDAR

Users can click the ‘Select file’ button to select a gantry LiDAR generated point cloud file for 3D trait analysis. In our work, we used FieldScan-acquired 3D point cloud data to demonstrate the 3D point processing procedure in CropQuant-3D.

1.5.1 Data pre-processing – denoising & filtering

Because most of the gantry system has integrated denoising and filtering methods, the generated point clouds normally do not need to go through denoising and filtering steps. Users can just select ‘No’ and ‘Ground points removed’ for both *Step 1* and *Step 2* (**Fig. S1.9**).

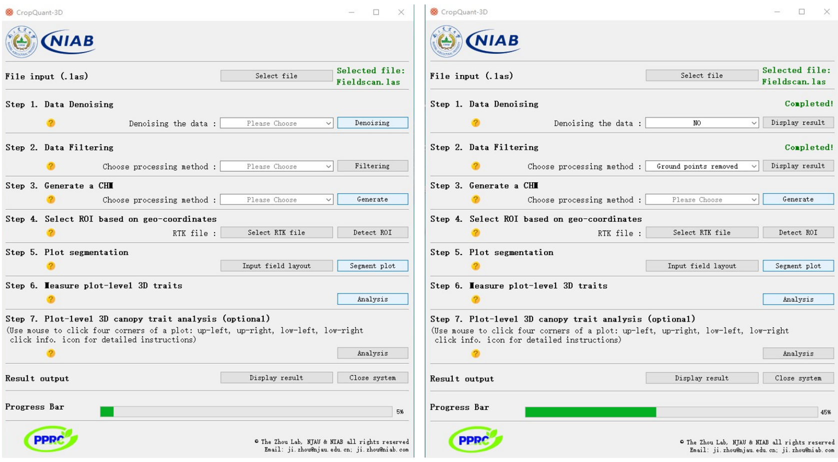

Figure S1.9 Denoising and filtering for point clouds generated by gantry LiDAR

1.5.2 Data pre-processing – display results

Users can click the ‘Display result’ button to display the newly processed point cloud file collected by the gantry LiDAR device in 3D (**Fig. S1.10**).

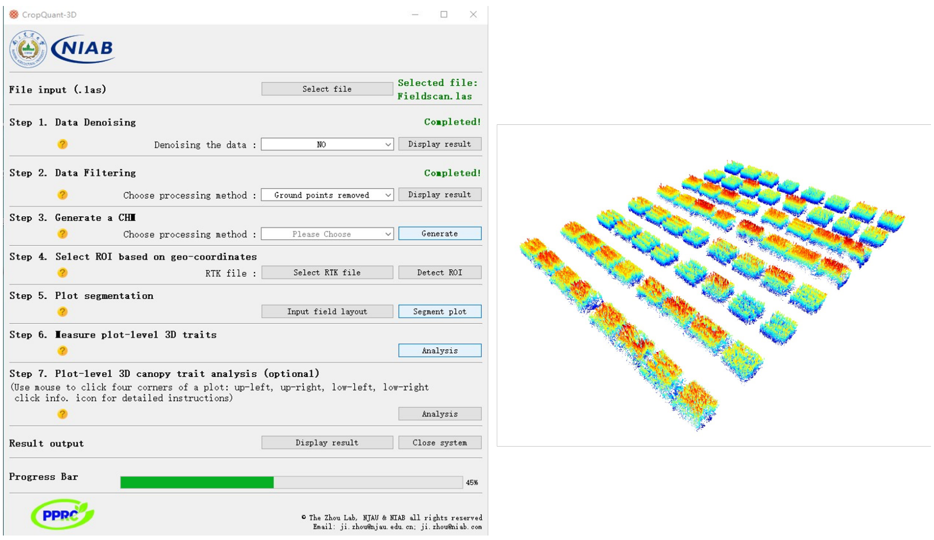

Figure S1.10 The visualisation of Gantry LiDAR collected point clouds

1.5.3 Data pre-processing – generating CHM

To create a 2D CHM file from the point clouds, the users need to select ‘Nearest neighbour gridding’ from the processing (**Fig. S1.11**, left). After pressing the ‘Generate’ button, a 2D Canopy Height Model (CHM) image will be created (**Fig. S1.11**, right).

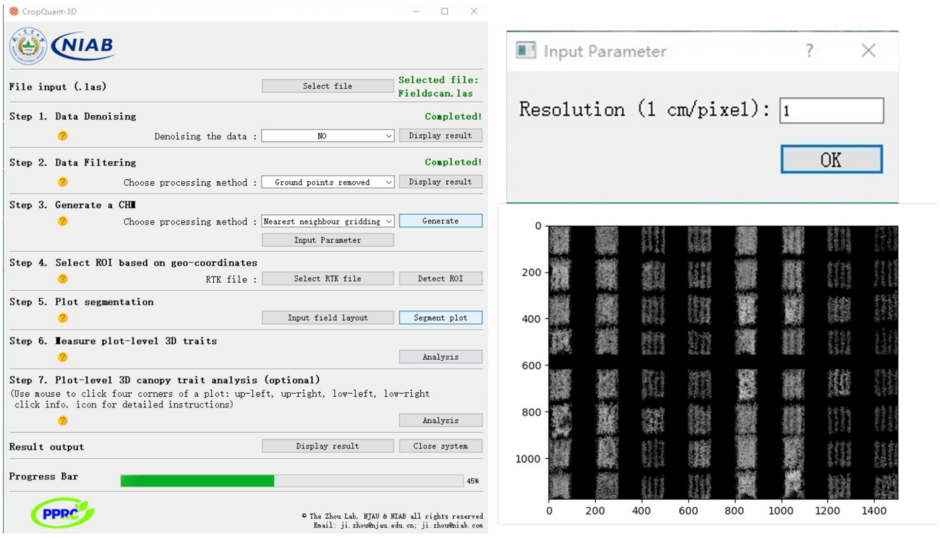

Figure S1.11 Generate CHM from the gantry LiDAR collected point clouds

1.6 Plot segmentation

For all types of input 3D point clouds, the 3D trait analysis steps are identical. Firstly, users need to create a 2D CHM file in the third step (**Fig. S1.12**). The default setting of the input parameter ‘Resolution’ is 1 (i.e. the exchange rate is 1 cm per pixel). Secondly, users need to press the ‘Generate’ button to create a 2D Canopy Height Model (CHM) image.

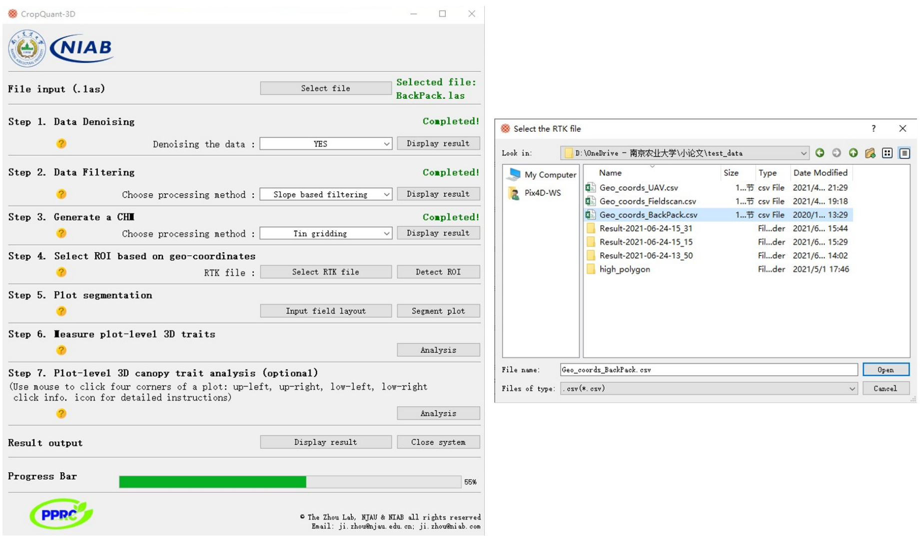

Figure S1.12 Plot segmentation procedure and its results

Then, users need to select regions of interest (ROI) to define the region for plot segmentation. Users are required to provide geo-coordinates, i.e. a RTK file. By clicking the ‘Define ROI’ button, the ROI of the experimental region can be defined. Finally, within the defined ROI, vertical and horizontal lines of the field can be detected by the CropQuant-3D. The default input parameters (i.e. Angle 1, Angle 2) are 360 and 30, which can be modified according to users' own CHM images. If the segmentation result misses some crop plots, users can add Input Paraments to provide optional inputs such as number of rows and columns in the field experiments (**Fig. S1.13**).

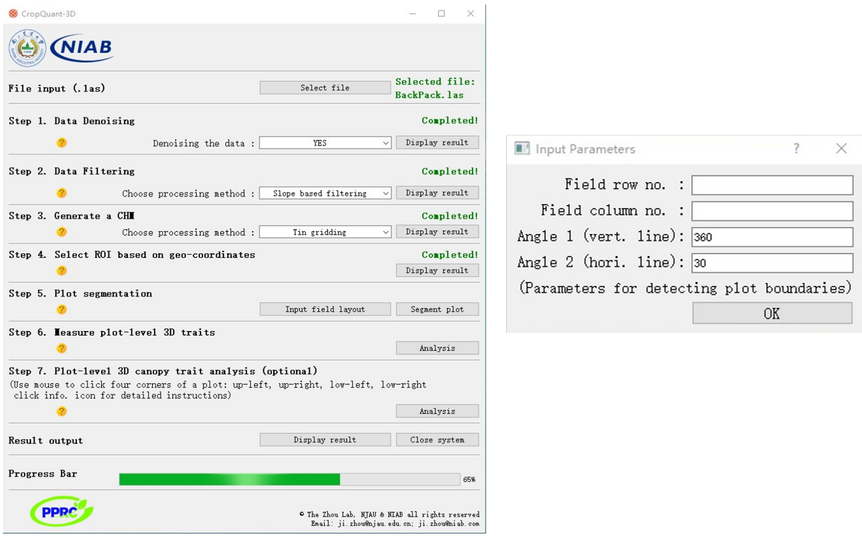

Figure S1.13 Plot segmentation procedure and its results

1.7 CHM and plot segmentation results of different types of point clouds

After the above steps, the results can be visualised by clicking the "Display result" button. The CHM images, ROIs, and plot segmentation results for point clouds collected through different data collection approaches can be displayed (**Figs. S1.14-16**).

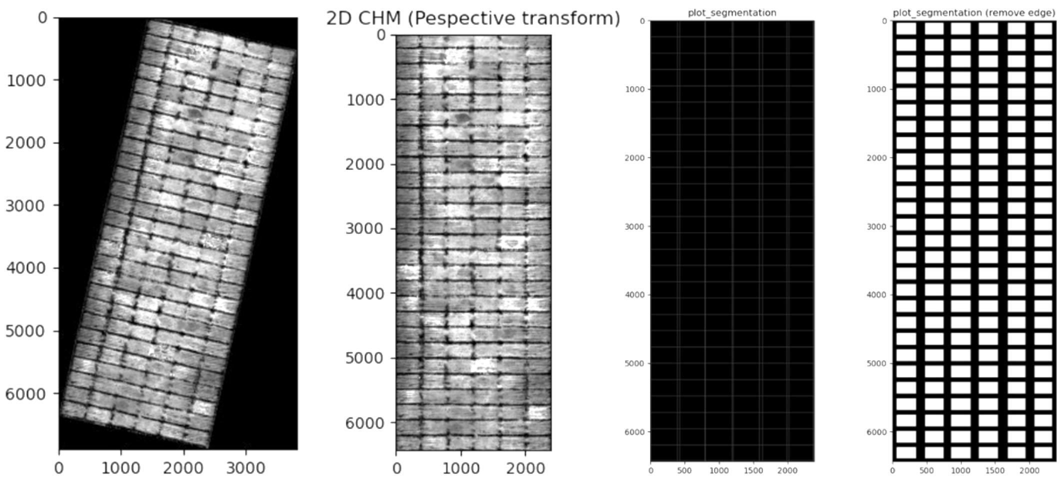

Figure S1.14 CHM, ROI and plot segmentation results for the backpack LiDAR

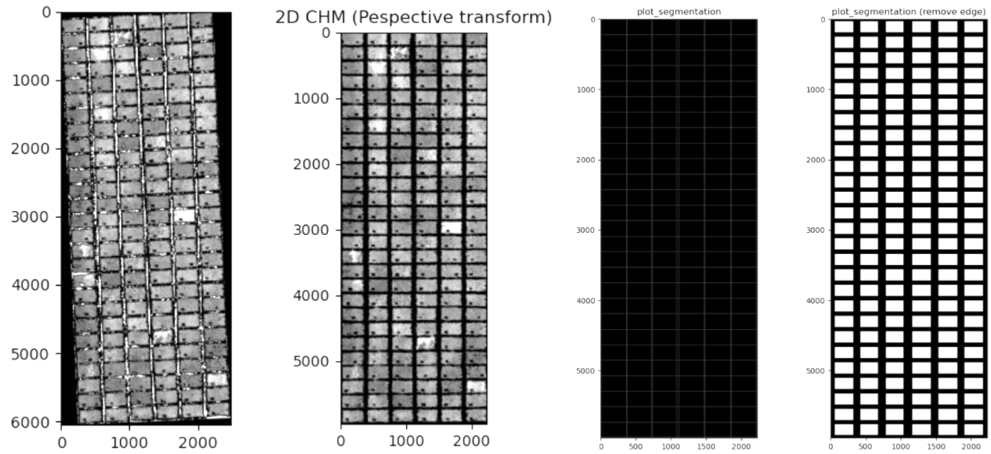

Figure S1.15 CHM, ROI and plot segmentation results for the UAV-SfM photogrammetry

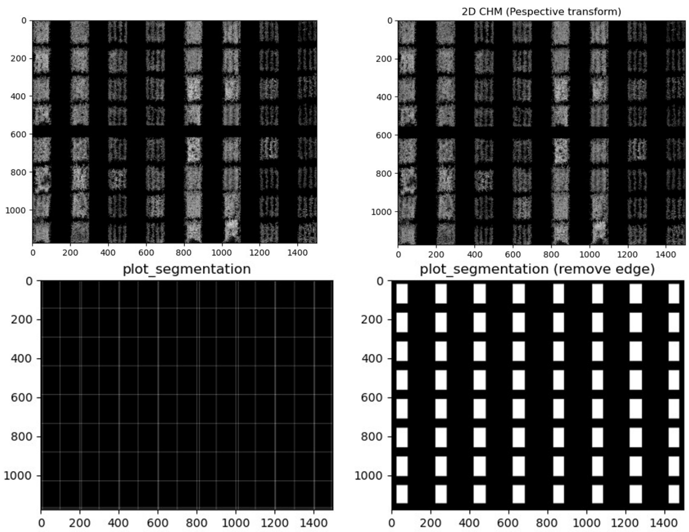

Figure S1.16 CHM, ROI and plot segmentation results for the gantry LiDAR

1.8 Trait Analysis

To analyse traits for all the plots, users just need to press the ‘Analysis’ button in the sixth step, which creates a new folder that contains images for all segmented plots as well as their plot-level traits such as height, canopy coverage, and canopy fluctuation in a .csv file. If users want to measure the plot-level 3D points, they shall click the ‘Analysis’ button and select plots in the pop-up window, following the order upper-left, upper-right, lower-left, to lower-right corners

1.9 Output and download results

After the analysis, users can click the ‘Download’ button to compress all output results in a zip file (**Fig. S1.17**). Also, users can open the result folder when the analysis is accomplished (all sections display green coloured “Completed1” working). The Close button will close the software.

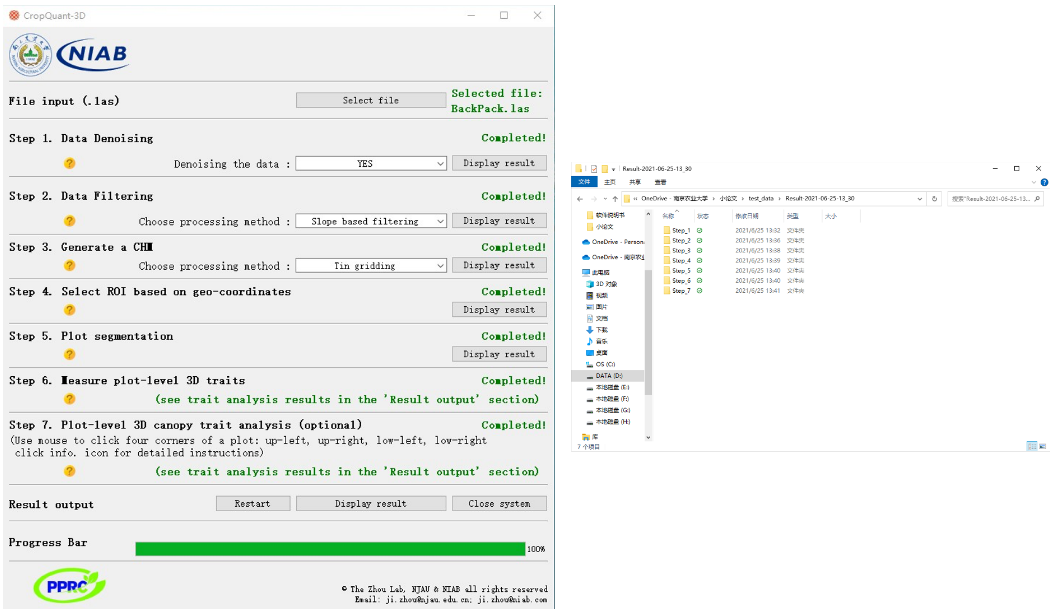

Figure S1.17 Results output and download