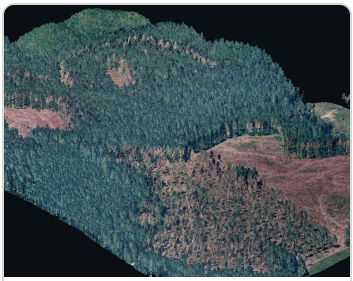
SilvaLiDAR Air

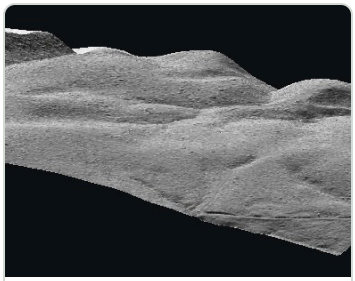
VERSION 0.1.8.80 · AIRBORNE LIDAR FOR FORESTRY

Introduction Guide to SilvaLiDAR Air

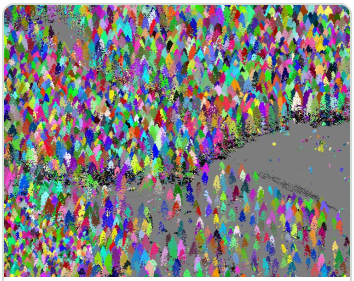
Ground and terrain models, canopy height, individual trees, plot and grid metrics, virtual forests and reports, one tool at a time, as saved workflows (SilvaFlow) or tile by tile over large areas (Catalog). Learn it step by step with an example point cloud.



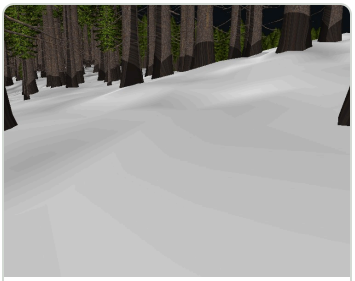
Point clouds
Explore millions of returns in 2D and 3D.



Terrain
Ground, DTM, hillshade, slope and contours.



Trees
Canopy height, gaps and every single tree.



Virtual forest
3D tree models you can click and walk through.

Example data Capitol State Forest, Washington: the FUSION/LDV sample point cloud (4.86 million returns with RGB, about 120 ha, EPSG:26910) and 60 illustration plots placed at random. **Editions** Standard and GPL (with CGAL-based tools): everything in this guide applies to both.

Contents

Part 1 · Getting started

Install SilvaLiDAR Air, then meet the window: every toolbar button, every menu item, the 2D and 3D scenes.

Part 2 · Reference

Data in and out, exploring the data, every processing tool, workflows and the command line, with pictures.

Part 3 · Exercises

13 illustrated, step-by-step exercises with the example data, from the first look at the data to workflows, large areas and the assistant.

Part 4 · Demonstrations

Real data the guide does not provide: drone, mobile and terrestrial scans of one plot, canopy gaps in a tropical forest, and AI classification of a city.

01 Install SilvaLiDAR Air and set up the example data

02 Getting started with SilvaLiDAR Air

03 Measuring and profiles

04 Clipping the LiDAR point cloud

05 From ground to terrain products

06 Canopy height and canopy gaps

07 Individual trees, the virtual forest and the forester

08 Plot and grid metrics, and your own metrics

09 Area-based modeling and mapping

10 Earth imagery and colorizing the cloud

11 Workflows with SilvaFlow

12 Large areas with SilvaFlow + Catalog

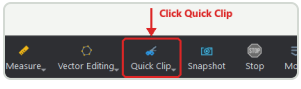
13 Pictures and videos

14 SilvaAI and the command line

How to use this guide

The steps

Verbs in *italics* are what you do; names in **bold** are what you see on screen. Menus are



A red ring and arrow show the toolbar button to click.

Tip A shortcut or a good default.

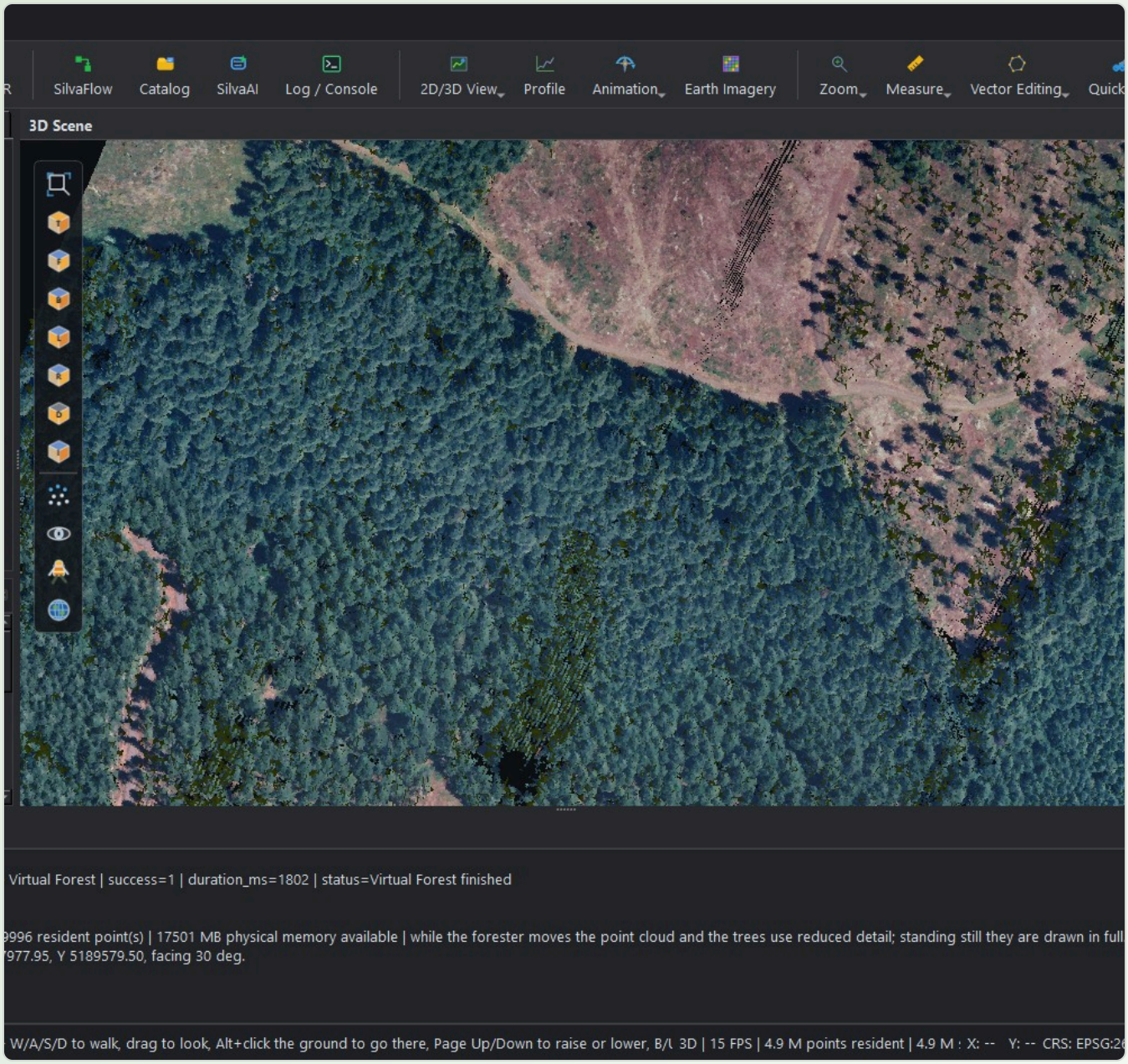
Note Something worth knowing.

Figures

Numbered by exercise (Figure 7.3). Click a picture in the web page to enlarge it.

written **Tools** › **Terrain** › **DTM**.

Important Read before you go on.



PART 1

Getting started

Install SilvaLiDAR Air and set up the example data (Exercise 1), then learn the window: every toolbar button and every menu item with what it does, the 2D map, the 3D scene and the Data panel. The exercises that follow use these names.

01 EXERCISE 1

INSTALL SILVALIDAR AIR AND SET UP THE EXAMPLE DATA

SilvaLiDAR Air 0.1.8.80

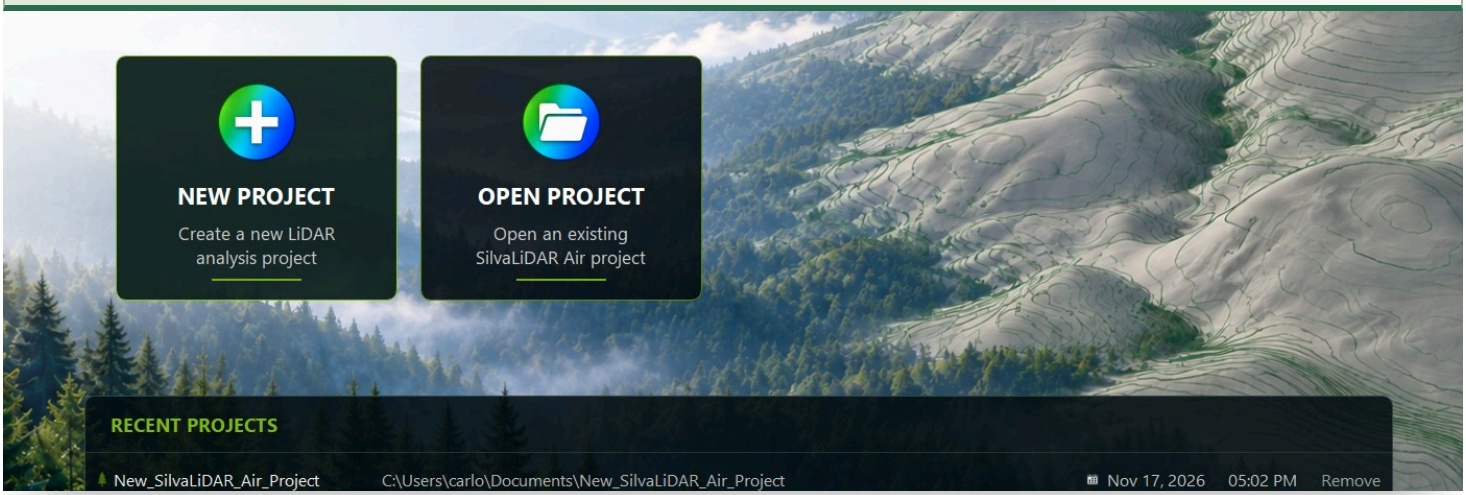


Figure 1.1 What you will make in this exercise.

Introduction

In this exercise you install SilvaLiDAR Air, download the exercise data, and create the project used in the rest of the exercises.

You will learn to

- ✓ Install either edition of SilvaLiDAR Air
- ✓ Organize the example data
- ✓ Create a project
- ✓ Fit the interface to your screen

Prerequisites

- A Windows 10 or 11 computer (64-bit) with at least 8 GB of memory
- About 2 GB of free disk space
- The SilvaLiDAR Air setup program or Portable package, and the exercise data (SilvaLiDARAirExercise.zip)

Overview of major steps

1. Run the setup, page by page
2. Download and extract the exercise data
3. Start SilvaLiDAR Air and create a project
4. Fit the interface to your screen

Procedure

Part 1: Start the setup

1. *Run* **SilvaLiDAR_Air_Setup_v0.1.8.80_claude_x64.exe** (or the GPL setup). If Windows shows **Windows protected your PC**, *Click* **More info** › **Run anyway** (only for a package you trust).
2. Windows asks whether Setup may make changes to the computer: *Click* **Yes**. SilvaLiDAR Air is installed for all users of the computer.

3. If an earlier version is installed, Setup says so first. *Keep* **Reinstall SilvaLiDAR Air and overwrite the existing application files** and *Click* **Next**: your projects and settings are kept.

> **Tip** Close SilvaLiDAR Air before you run Setup. Setup closes it for you, and anything not saved would be lost.

> **Note** Without installing: *unzip* the **Portable** package to a folder of your choice and *run* **SilvaLiDARAir.exe** in it.

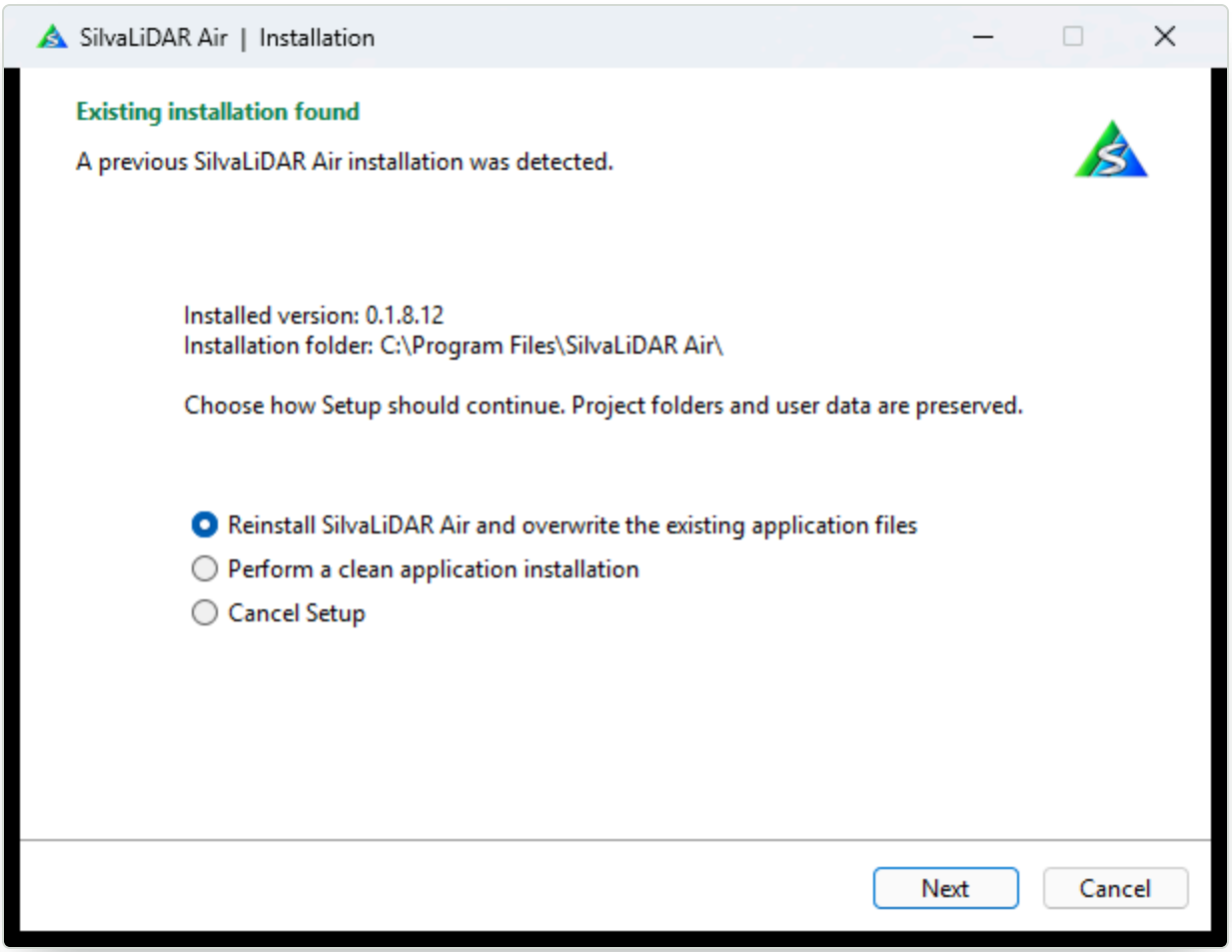


Figure 1.2 Existing installation found: shown only when an earlier version is installed.

Part 2: Choose the folder

1. **Select Destination Location** proposes **C:\Program Files\SilvaLiDAR Air**. *Keep* it (or *Click* **Browse…** for another folder) and *Click* **Next**.
2. The page shows how much free disk space the program needs (about 200 MB).

> **Tip** Two editions exist: the standard one and the **GPL** edition, which adds tools built on the CGAL library. Both work with every exercise in this guide.

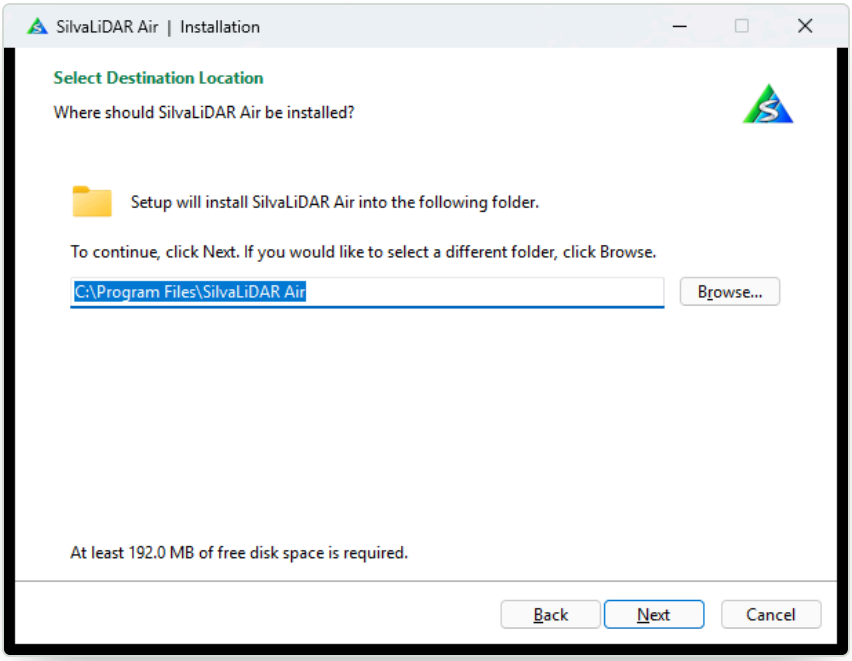


Figure 1.3 Select Destination Location.

Part 3: Shortcuts

1. **Select Additional Tasks**: ***keep*** **Create a desktop shortcut** ticked to start SilvaLiDAR Air from the desktop, and ***Click*** **Next**.
2. A **SilvaLiDAR Air** entry is always added to the Start menu.

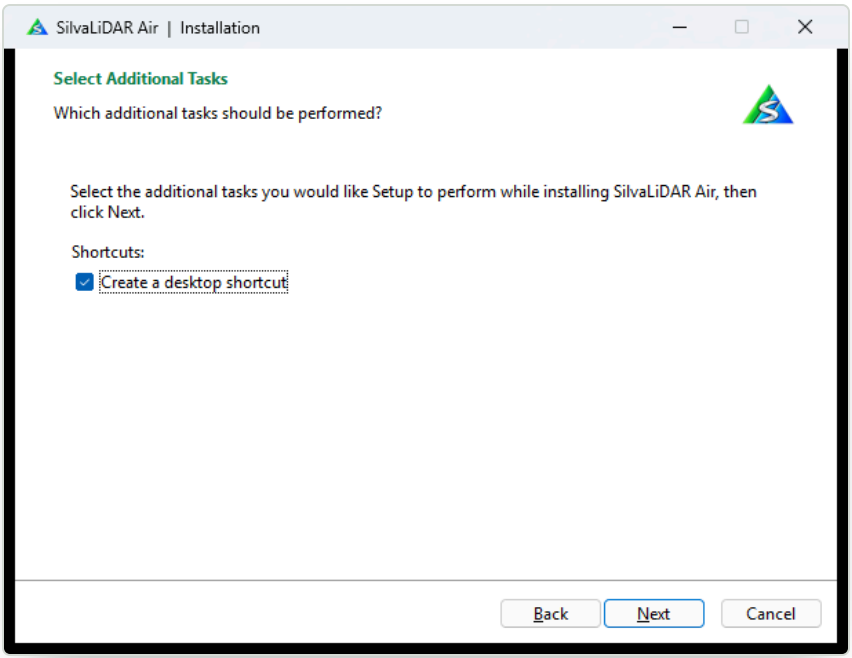


Figure 1.4 Select Additional Tasks.

Part 4: Install

1. **Ready to Install** sums up the folder and the shortcuts. *Click* **Back** to change them, or *Click* **Install**.
2. **Installing** shows the files being copied; it takes under a minute.

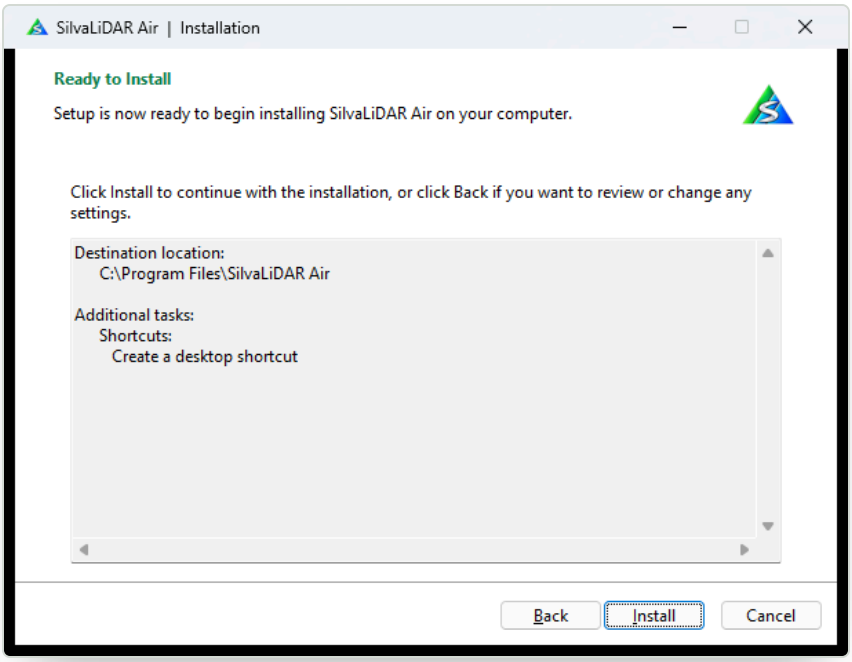


Figure 1.5 Ready to Install.

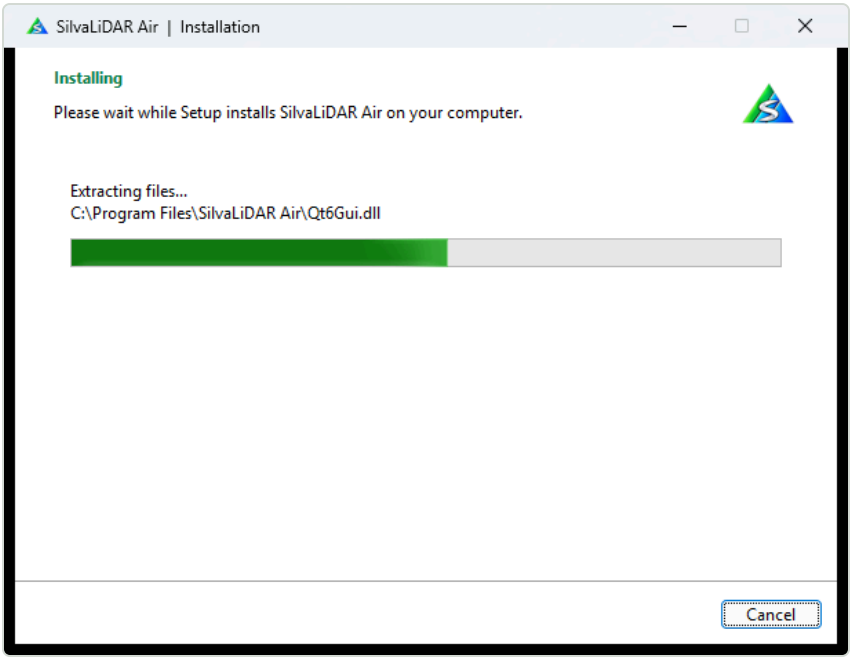


Figure 1.6 Installing.

Part 5: Finish

1. **Completing the SilvaLiDAR Air Setup Wizard**: *leave* **Launch SilvaLiDAR Air** ticked to start it now, and *Click* **Finish**.

2. Later, *start* it from the desktop shortcut or the Start menu.

> **Note** SilvaLiDAR Air never changes your LAS/LAZ files: every tool writes new files.

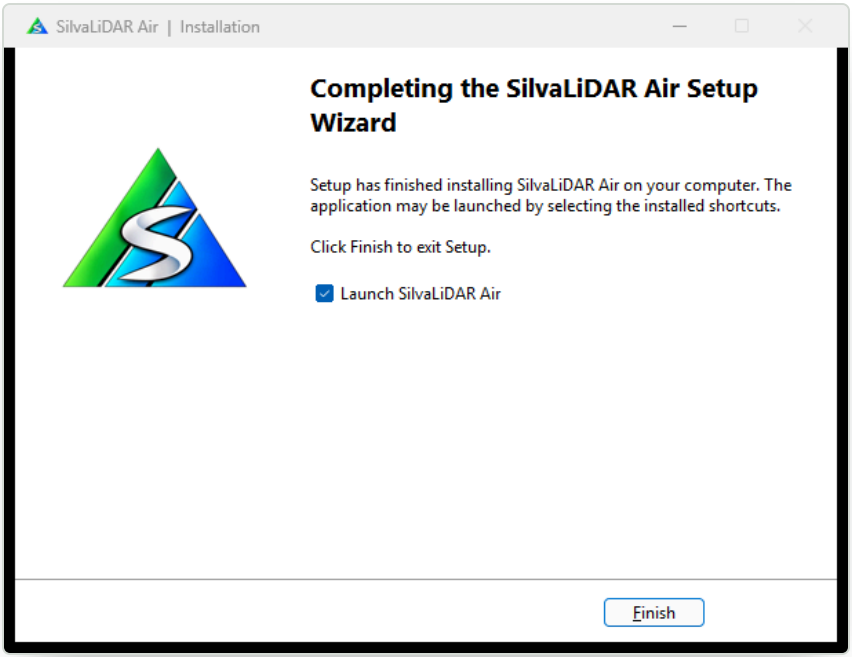


Figure 1.7 The last page of Setup.

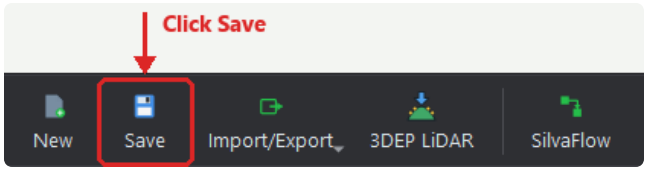
Part 6: Get the exercise data

1. *Download* **SilvaLiDARAirExercise.zip** (445 MB) from https://github.com/carlos-alberto-silva/SilvaLiDAR-Air-data/releases/download/exercise-data-v1/SilvaLiDARAirExercise.zip.
2. *Right-click* the zip › **Extract All…**, *type* **C:** as the destination and *Click* **Extract**: you get **C:\SilvaLiDARAirExercise**.
3. The point cloud of the exercises is **C:\SilvaLiDARAirExercise\01_Sites\01_CapitolStateForestWA\01_LAZ\CapitolForest.laz** and the plots are **C:\SilvaLiDARAirExercise\01_Sites\01_CapitolStateForestWA\02_SHP\plots_poly.shp**. *Create* the folder **C:\SilvaLiDARAirExercise\03_Projects\cli_out**: the command-line steps of later exercises write there.
4. **The exercise data** page, at the start of Part 3, describes every folder and file.

> **Tip** Keep the path short and without spaces: it is easier to type in the command-line steps. Another folder works too; then change the paths of the examples.

> **Note CapitolForest.laz** is the FUSION/LDV sample point cloud (USDA Forest Service). The 60 plots of **plots_poly.shp** were placed at random to illustrate the plot tools; they are not field plots. **Data_credits.txt** in the zip lists the source and citation of every dataset.

Part 7: Start SilvaLiDAR Air and create a project



1. *Start* **SilvaLiDAR Air** from the Start menu (or **SilvaLiDARAir.exe**). The **Home** window opens.
2. *Click* **New project**, *name* it **Exercises** and *choose* a folder for it, for example **C:\SilvaLiDARAirExercise\03_Projects**.
3. The main window opens with an empty project. *Click* **Save** on the toolbar from time to time to save it.

Part 8: Fit the interface to your screen

1. *Open* **View** › **GUI Properties…**.
2. *Choose* an **Application theme** (SilvaLiDAR Dark is the default; Studio Light prints well).
3. On a small laptop screen, *set* **Interface size** to **Automatic** (or a smaller size if a toolbar button is still hidden). It applies the next time SilvaLiDAR Air starts.

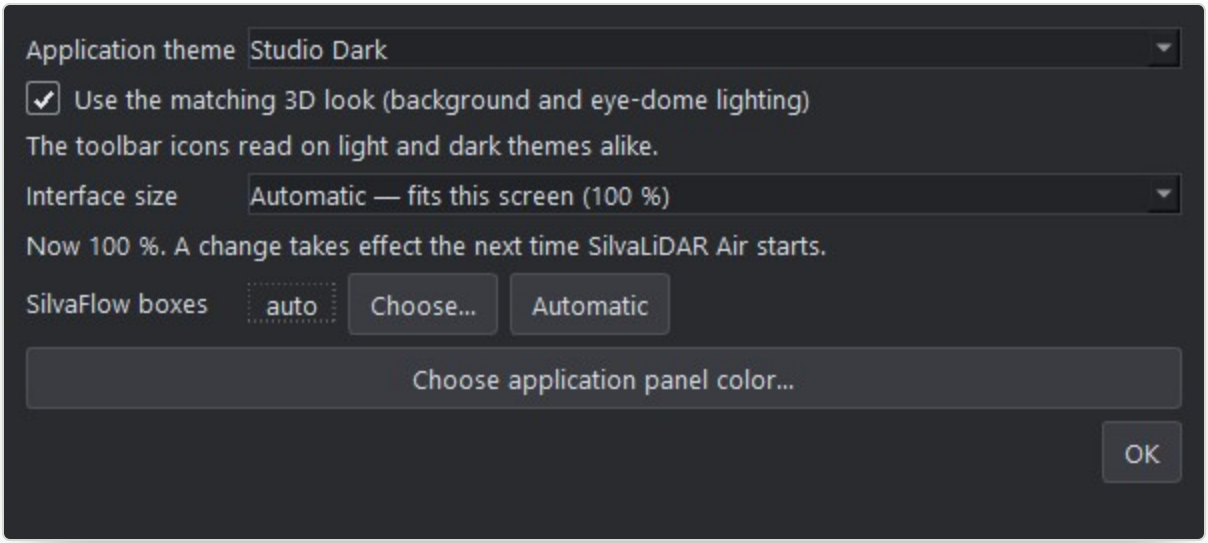


Figure 1.8 View › GUI Properties.

Result SilvaLiDAR Air is installed, the exercise data are in place and the **Exercises** project is open.

Did you know? A project remembers which point-cloud files it uses, not their contents: keep the source files where they are, or re-point the project if you move them.

Check your understanding

1. Where are the products of a single tool written inside the project folder?
2. Which Interface size would you choose on a 1366 × 768 laptop, and when does the change take effect?

About SilvaLiDAR Air

SilvaLiDAR Air processes airborne laser scanning (ALS) point clouds for forestry and terrain: from the raw LAS/LAZ file to terrain models, canopy height, individual trees, plot and grid metrics, area-based models, 3D visualization and reports, without writing code. It works in three ways that share the same engines: one tool at a time (Standalone), as a saved workflow (SilvaFlow), and tile by tile over large areas (SilvaFlow + Catalog). A command-line program and an AI assistant (SilvaAI) complete it. Your LAS/LAZ files are never modified: every tool writes new files.

Projects

File menu · New and Save buttons

A project is a folder that keeps the layers you load, the products of every tool, the logs and the SilvaFlow workflow. It remembers which point-cloud files it uses, not their contents, so keep the source files where they are. Everything the program makes for the project stays in its folder (nothing is written beside your data), so deleting the folder deletes all of it and nothing else.

1. New Project clears layers, results and workflow; Save writes the .slair file and its state.
2. Products of single tools go to `Standalone/Products`, Catalog runs to `Catalog`, logs to `Logs`; Quick Clips, display copies and the lists of tile collections to `Cache`.
3. File › Project Info shows each part of the project and the space it takes, with Open project folder and Clear display copies. `PROJECT_INFO.txt` in the project folder holds the same table and the list of input files, written again at every save, so a project can be checked without opening the program.

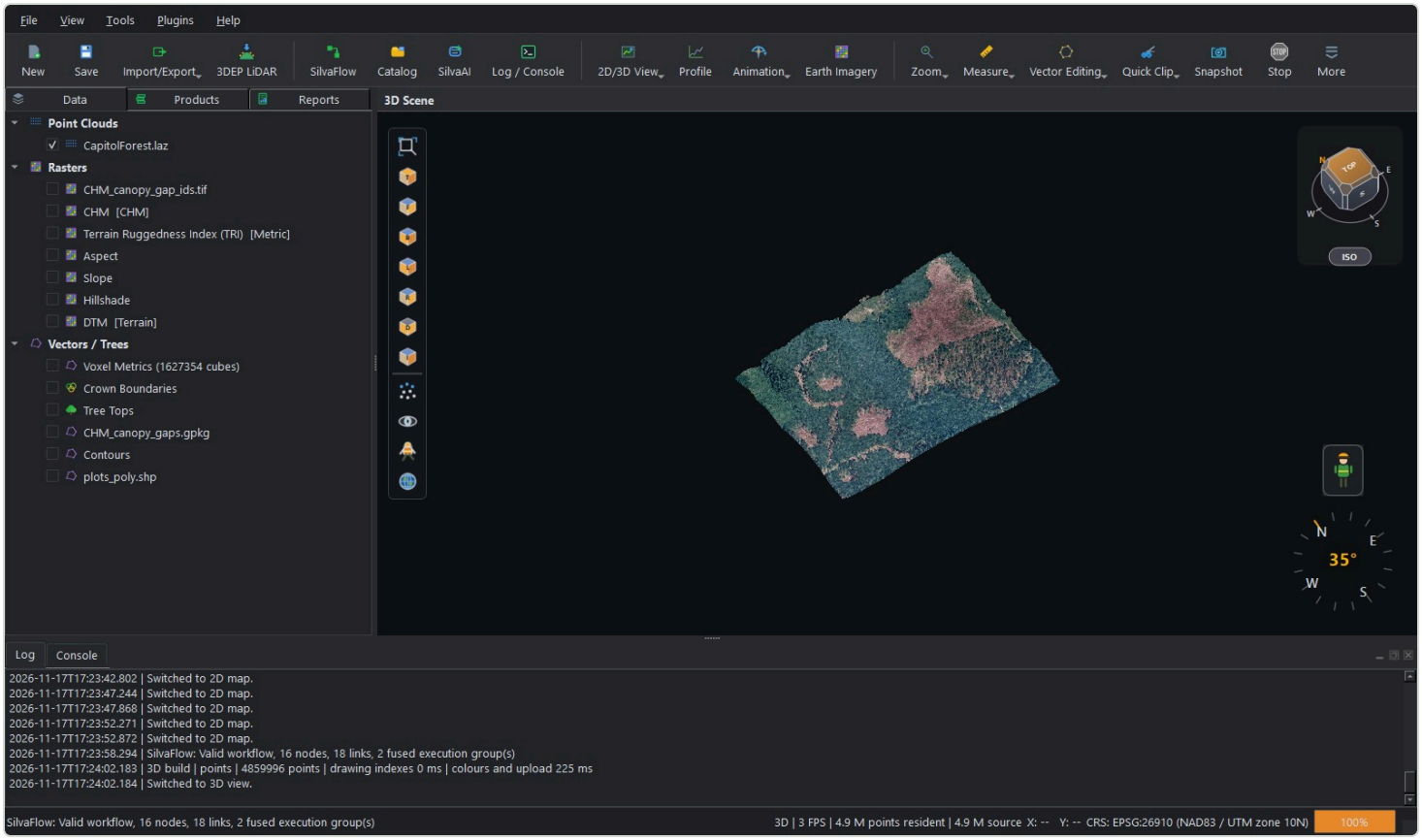
D:\SilvaLaserAir_guide_capture_v01862\ui

Part	Where	Files	Size
Input files (referenced, not copied)	C:\Users\carlo\Documents\SilvaLaserAir\03_Data\01_ALS\CapitolForest	1	49.3 MB
Display copies (remade when needed)	Cache\Display	0	0 KB
Quick Clips	Cache\QuickClip	0	0 KB
Collection files (.slp, .slc)	Cache\Collections	0	0 KB
Other cache	Cache	0	0 KB
Products and reports	Standalone, SilvaFlow, Catalog, Modeling, Products	0	0 KB
Logs	Logs	0	0 KB
Project file, state and other files	(project folder)	34	1.9 MB
Total in the project folder		**34**	**1.9 MB**

Deleting the project folder deletes everything counted in it, and nothing else: the input files stay where they are. The display copies, Quick Clips and collection files are remade when needed. 4852.63 GB free on this disk.

Open project folder | Clear display copies | Close

File › Project Info: what the project holds and the space each part takes.



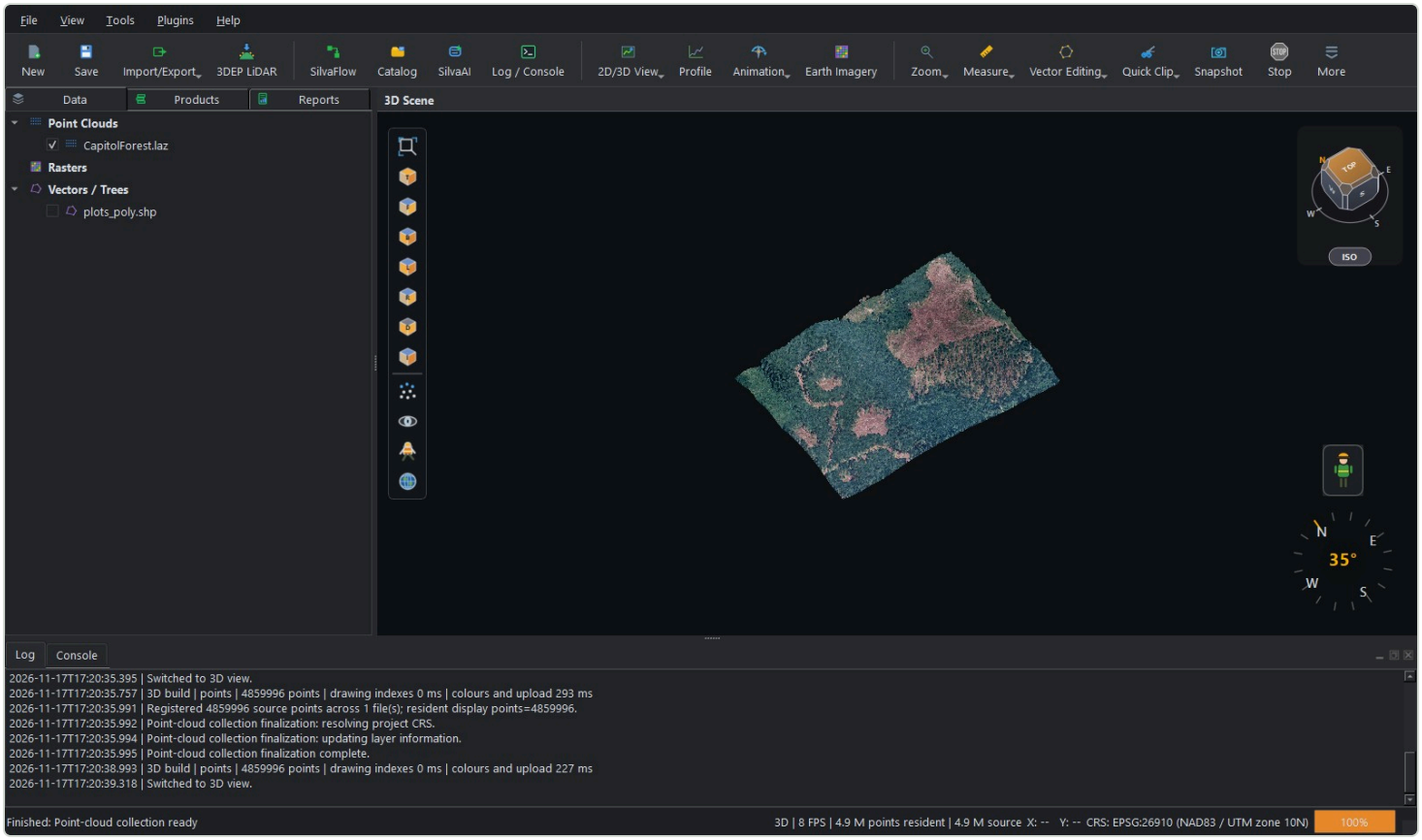
A project in the workspace: the layers and products it keeps in the Data panel.

The interface

Every part of the window, every toolbar button, every menu item, and the controls of the 2D and 3D scenes.

The window

The toolbar runs along the top under the menus. The left panel lists your Data, Products and Reports; the centre shows the 2D map or the 3D scene; the bottom panel holds the Log and the Console; the status bar shows messages, progress, cursor coordinates and the CRS.

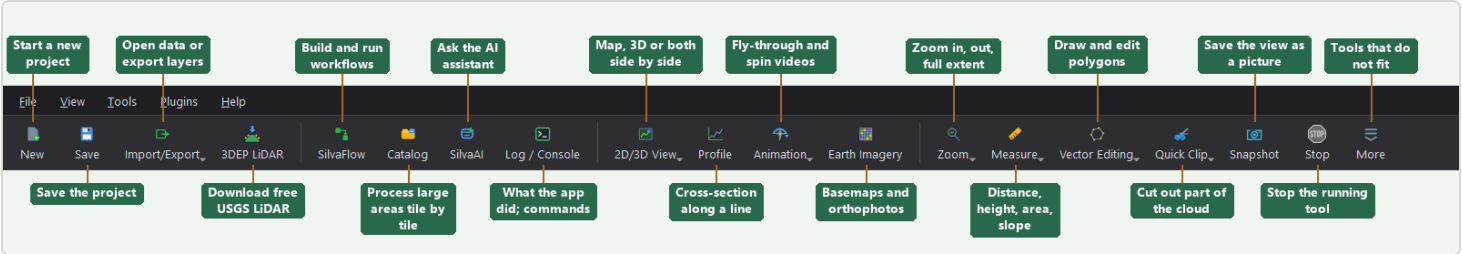


The window with a point cloud open in the 3D Scene.

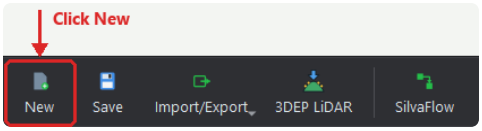
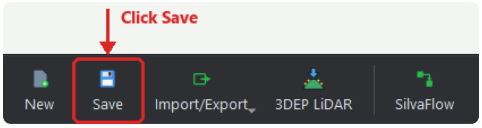
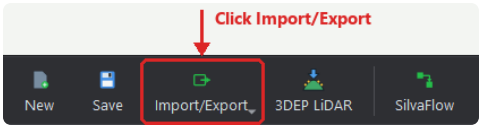
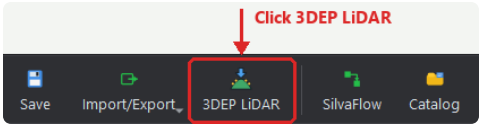
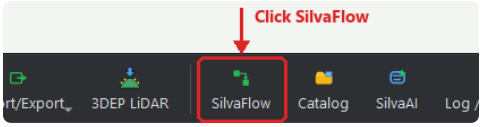
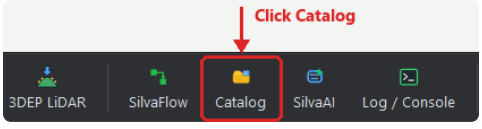
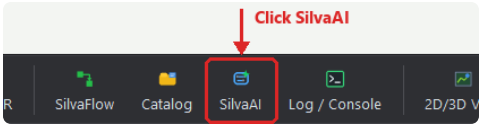
- Right-click a layer in the Data panel for its options; its checkbox turns the display on or off.

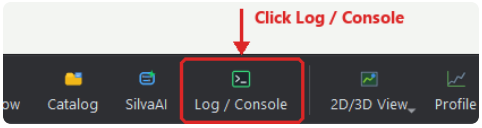
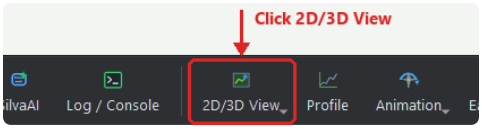
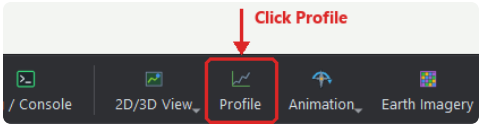
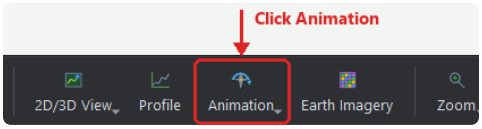
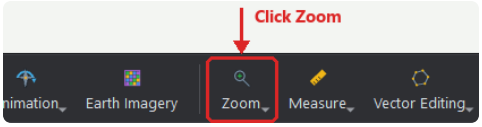
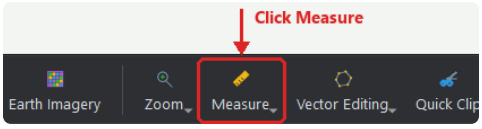
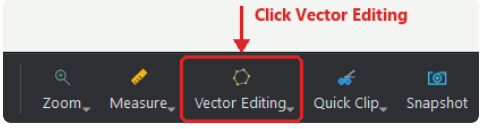
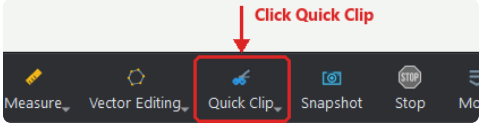
The toolbar

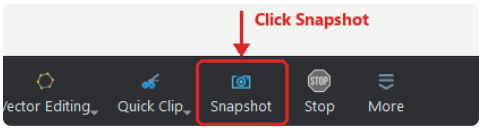
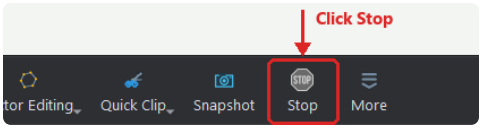
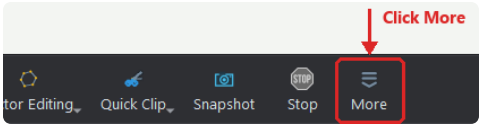
What each button does. A small arrow under a button means it opens a menu; those menus follow the table.

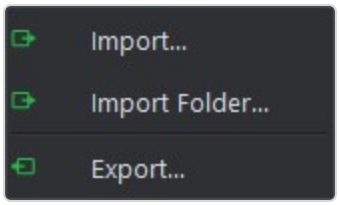


What each toolbar button does.

BUTTON	WHAT IT DOES
 **New**	Start a new, empty project.
 **Save**	Save the project file (.slair) with its layers, settings and workflow.
 **Import/Export**	Import LAS/LAZ/COPC, rasters or vectors; Import Folder registers every LAS/LAZ of a folder; Export writes point clouds, rasters, vectors, tables or 3D products.
 **3DEP LiDAR**	Find and download free USGS 3D Elevation Program LiDAR for an area of the United States.
 **SilvaFlow**	Open the workflow editor: chain tools into a graph and run them together.
 **Catalog**	Open the Catalog panel: run a SilvaFlow tile by tile over large areas.
 **SilvaAI**	Open the AI assistant that explains tools and can build and run workflows.

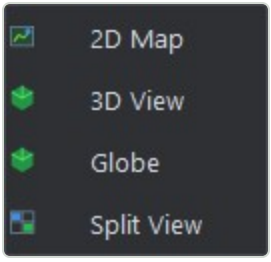
BUTTON	WHAT IT DOES
 **Log / Console**	Show the Log (what the program did, in order) and the command Console.
 **2D/3D View**	Switch between the 2D map, the 3D scene, or both side by side.
 **Profile**	Draw a line on the 2D map to see a vertical cross-section of the points.
 **Animation**	Flight Through and Spin: animate the 3D scene and export MP4 videos.
 **Earth Imagery**	Add a live basemap or imagery clipped to the project (NAIP, USGS maps, Mapbox, your own XYZ/TMS tiles, local GeoTIFF).
 **Zoom**	Zoom in, zoom out, or back to the full extent of the data.
 **Measure**	Horizontal and 3D distance, vertical height, area and perimeter, slope, angle and point query.
 **Vector Editing**	Draw polygons and rectangles, edit attributes and vertices, and save them.
 **Quick Clip**	Select part of the cloud with a polygon or box, in 2D or 3D, and keep it (IN) or remove it (OUT).

BUTTON	WHAT IT DOES
 **Snapshot**	Save the current 2D, 3D or split view as an image.
 **Stop**	Stop the tool, workflow or Catalog run that is processing.
 **More**	On narrow windows: the tools that do not fit in the toolbar.



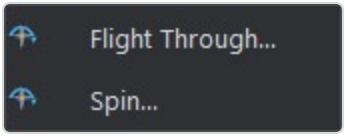
Import/Export menu

- **Import...** — Import LAS/LAZ/COPC, raster, or vector data
- **Import Folder...** — Import all LAS/LAZ files from a folder
- **Export...** — Export point cloud, raster, vector, table, or 3D products



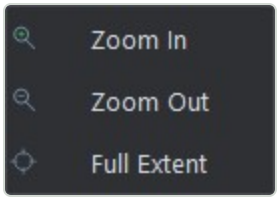
2D/3D View menu

- **2D Map**
- **3D View**
- **Globe**
- **Split View**



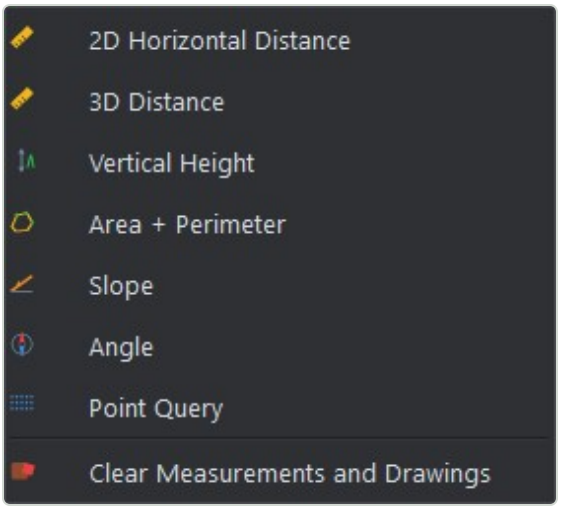
Animation menu

- **Flight Through...** — Fly through the 3D scene along captured views or a path drawn on the 2D map, and export a video
- **Spin...** — Turn the 3D view around a centre point, and export a video



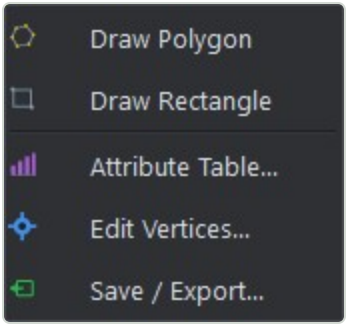
Zoom menu

- **Zoom In**
- **Zoom Out**
- **Full Extent**



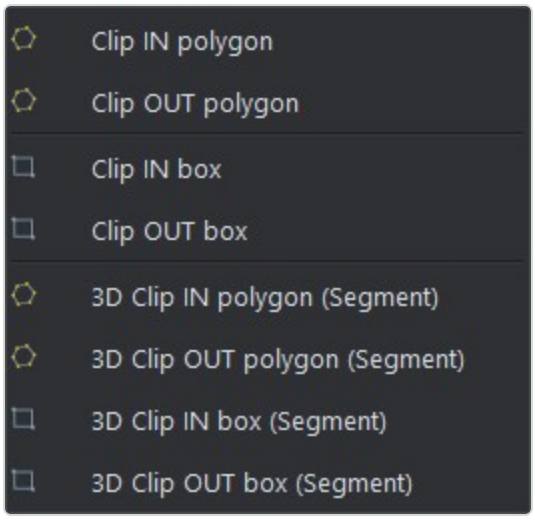
Measure menu

- **2D Horizontal Distance**
- **3D Distance**
- **Vertical Height**
- **Area + Perimeter**
- **Slope**
- **Angle**
- **Point Query**
- **Clear Measurements and Drawings**



Vector Editing menu

- **Draw Polygon**
- **Draw Rectangle**
- **Attribute Table...** — Attribute Table
- **Edit Vertices...** — Edit Vertices
- **Save / Export...** — Save / Export



Quick Clip menu

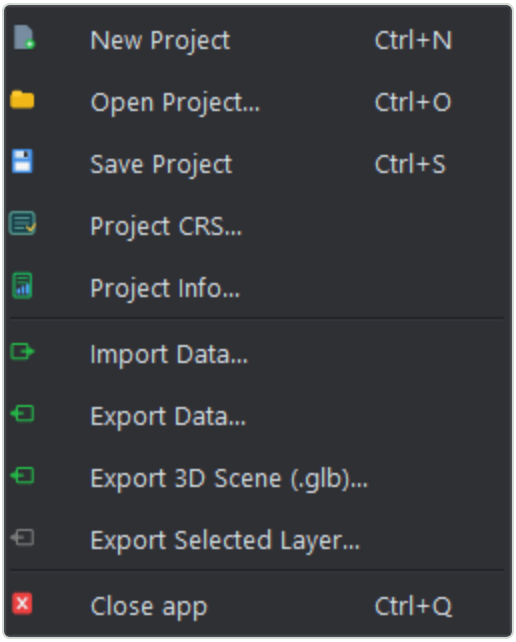
- **Clip IN polygon**
- **Clip OUT polygon**
- **Clip IN box**
- **Clip OUT box**
- **3D Clip IN polygon (Segment)**
- **3D Clip OUT polygon (Segment)**
- **3D Clip IN box (Segment)**
- **3D Clip OUT box (Segment)**

- On a narrow window the labels under the icons are hidden first, so every button stays visible.

The menus

Every menu and submenu, with what each item does, and the window it opens.

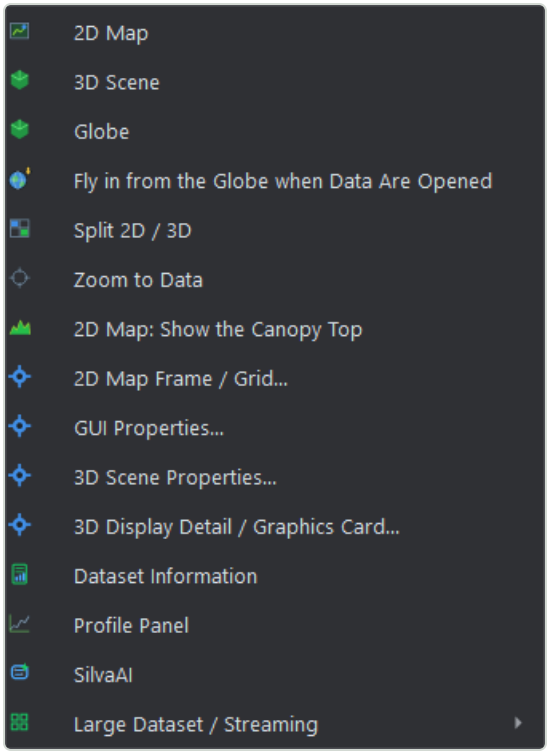
File



New Project `Ctrl+N`	Clear the session and start a new project folder.
Open Project... `Ctrl+O`	Open a saved .slair project with its layers, products and workflow.
Save Project `Ctrl+S`	Save the project file and its state.
Project CRS...	Set the coordinate system used by every layer that has none of its own.
Project Info...	Shows what the project holds and the space each part takes (input files, display copies, Quick Clips, products, logs), with buttons to open the folder and clear the display copies.
Import Data...	Open point clouds (LAS/LAZ/COPC), rasters or vectors.
Export Data...	Export point clouds, rasters, vectors, tables or 3D products.
Export 3D Scene (.glb)...	Save what the 3D Scene shows (virtual forest, terrain, points, vectors, 3D crowns) as one glTF scene for Blender or Unity.

Export Selected Layer...	Export the layer selected in the Data panel exactly as it is.
Close app `Ctrl+Q`	Close SilvaLiDAR Air.

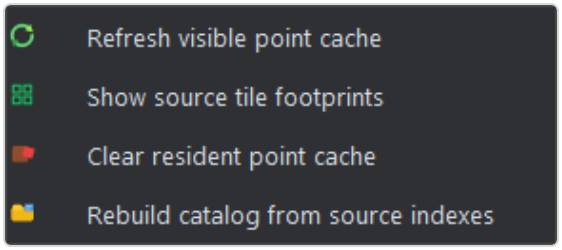
View



2D Map	Show the 2D map.
3D Scene	Show the 3D scene.
Globe	A globe of the Earth (NASA Blue Marble imagery) with your data placed on it; the camera flies down to the data.
Fly in from the Globe when Data Are Opened	When ticked, opening data starts on the globe and flies down to it.
Split 2D / 3D	Map and 3D scene side by side.
Zoom to Data	Fit both views to the loaded data.
2D Map: Show the Canopy Top	Each map pixel shows the highest return under it: the canopy as seen from above.
2D Map Frame / Grid...	Frame, coordinate grid, ticks, labels and titles for 2D map figures.
GUI Properties...	Theme, interface size and SilvaFlow box colour.

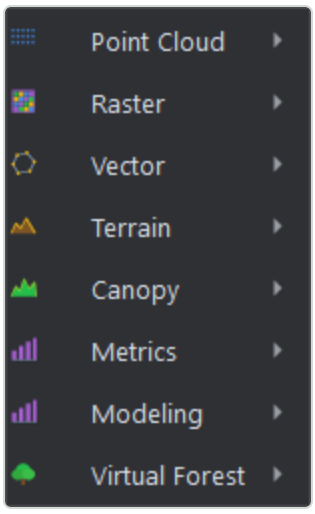
3D Scene Properties...	Background, lighting, axes, scale bar and other 3D display options.
3D Display Detail / Graphics Card...	Shows the graphics card found and sets how much detail the 3D Scene draws, the full-detail point limit (Auto follows the computer), how large data open (Full detail, Preview only, Bounding boxes only), and where the display copies are kept (the project's folder by default) and how much space they may use.
Dataset Information	The Point Cloud Information panel: CRS, files, points, extent.
Profile Panel	Show the Point Cloud Profile panel.
SilvaAI	Show the SilvaAI assistant.
Large Dataset / Streaming ▸	Display controls for streamed collections of large files.

View › Large Dataset / Streaming



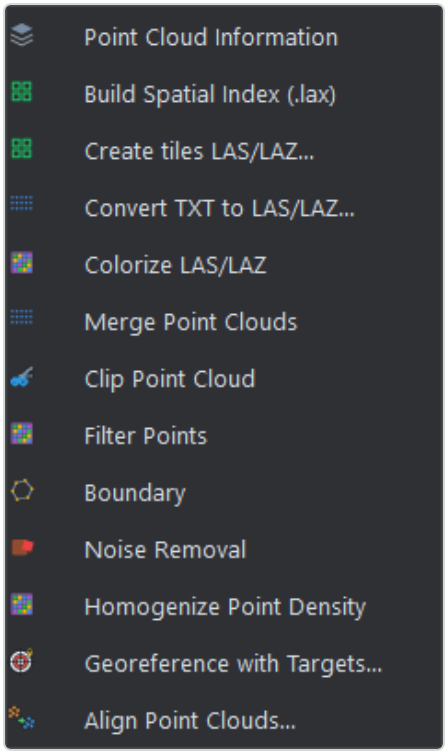
Refresh visible point cache	Read the visible part of a streamed collection again.
Show source tile footprints	Draw the outline of every source file on the map.
Clear resident point cache	Free the memory used by points held for display.
Rebuild catalog from source indexes	Rebuild the collection's index from the files' .lax indexes.

Tools



Point Cloud ▸	Point-cloud utilities.
Raster ▸	Raster utilities.
Vector ▸	Vector utilities and drawing.
Terrain ▸	Ground, DTM, normalization and terrain analysis.
Canopy ▸	Classification, CHM, gaps and trees.
Metrics ▸	Plot, grid, voxel and tree metrics.
Modeling ▸	Area-based and voxel-based modeling.
Virtual Forest ▸	3D tree models on the detected trees.

Tools › Point Cloud



Point Cloud Information	Header summary of the loaded clouds: points, extent, CRS, attributes.
Build Spatial Index (.lax)	Write a .lax index beside each LAS/LAZ for fast reads of an area.
Create tiles LAS/LAZ...	Split clouds into square tiles with an optional overlap buffer.
Convert TXT to LAS/LAZ...	Turn XYZ text files into LAS/LAZ.
Colorize LAS/LAZ	Write RGB from an orthophoto or other raster into the points.
Merge Point Clouds	Join several LAS/LAZ into one file.
Clip Point Cloud	Cut the cloud by polygons, or by point plots with a radius.
Filter Points	Keep only the points that pass your criteria (classes, height above ground, return type, intensity) for the tools that follow; the file is not changed.
Boundary	Outline of the area covered by the points, as a polygon.

Noise Removal	Remove or flag isolated points above and below the surface.
Homogenize Point Density	Cap the points per cell so overlapping flight lines do not bias metrics.
Georeference with Targets...	Carry a cloud in local coordinates onto surveyed targets: pick them, give their coordinates, fit by least squares and check each target's residual.
Align Point Clouds...	Move clouds from other sensors or surveys onto a reference (coarse match, then ICP on the ground and trunks), and optionally merge them.

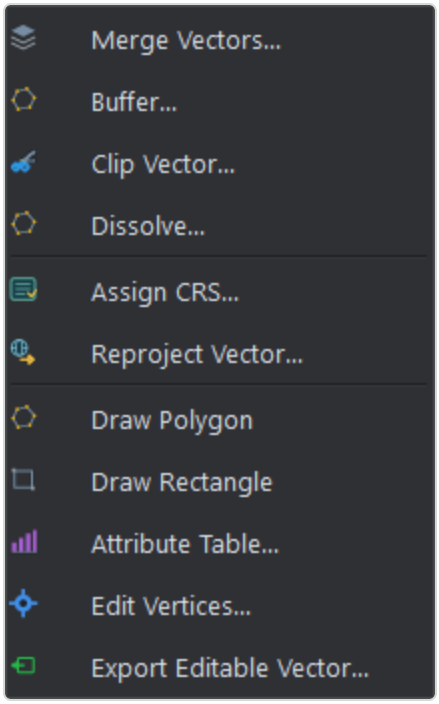
Tools › Raster



Merge Rasters...	Mosaic several rasters into one.
CSV to Grid...	Make a raster from a table of X, Y and values.
Clip Raster...	Cut a raster by polygons or an extent.
Assign CRS...	Declare the CRS of a raster that has none (nothing is moved).

Reproject Raster...	Transform a raster into another CRS.
Validate with Ground Points...	Compare GNSS or field points with a DTM, CHM or raster: bias, RMSE, NMAD, LE95, R^2, a 1:1 plot, distributions and a map of the errors.

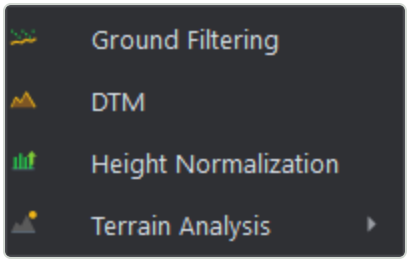
Tools › Vector



Merge Vectors...	Join several vector layers.
Buffer...	Grow features by a distance (plot centres into circular plots).
Clip Vector...	Cut a vector layer by polygons.
Dissolve...	Merge polygons that share an attribute value.
Assign CRS...	Declare the CRS of a vector that has none.
Reproject Vector...	Transform a vector layer into another CRS.
Draw Polygon	Draw a polygon on the 2D map (double-click to finish).
Draw Rectangle	Draw a rectangle with two clicks.
Attribute Table...	View, filter and edit attributes.

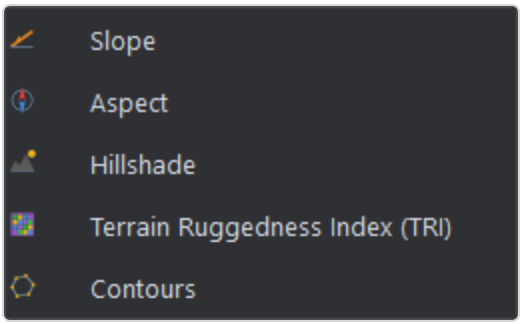
Edit Vertices...	Move, add or delete vertices.
Export Editable Vector...	Save drawn polygons as GeoPackage, GeoJSON or Shapefile.

Tools › Terrain



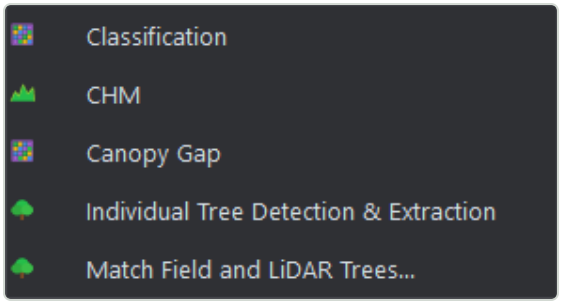
Ground Filtering	Classify ground returns (class 2): PTD, MCC, CSF, PMF, SMRF, WLS, MV-HCS or AMT.
DTM	Interpolate the bare-earth terrain model.
Height Normalization	Turn elevations into heights above ground.
Terrain Analysis ▸	Slope, aspect, hillshade, TRI and contours from the DTM.

Tools › Terrain › Terrain Analysis



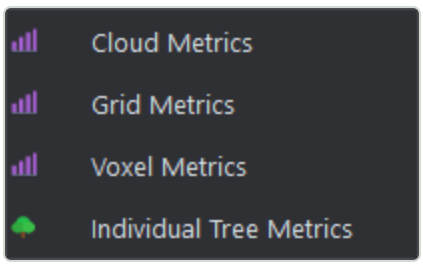
Slope	Steepness of the terrain, in degrees.
Aspect	Direction the slope faces.
Hillshade	Shaded relief of the DTM.
Terrain Ruggedness Index (TRI)	How much the elevation changes around each cell.
Contours	Contour lines from the DTM.

Tools › Canopy



Classification	Classify points: geometric rules (ground, vegetation, buildings), or an AI model you train from labelled points (Random Forest, PointNet, PointNet++, PointNeXt); also labels points and applies saved models.
CHM	Canopy height model.
Canopy Gap	Openings in the canopy below a height, with their area.
Individual Tree Detection & Extraction	Find each tree: tree IDs on the points, tree tops and crowns.
Match Field and LiDAR Trees...	Pair field-measured trees with the detected trees: matched, omissions, commissions, F-score and the errors of the matched trees.

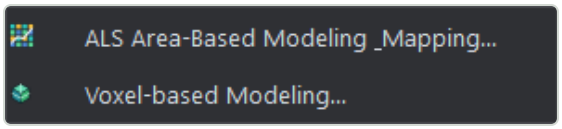
Tools › Metrics



Cloud Metrics	Metrics of the clouds you pass (the stand, a clip, or each of several files), with your own custom metrics.

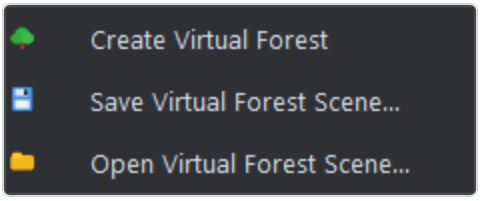
Grid Metrics	Metrics, yours included, for every cell of a grid, as a table and GeoTIFFs.
Voxel Metrics	Metrics in 3D cells.
Individual Tree Metrics	Height, crown and volume of every tree.

Tools › Modeling



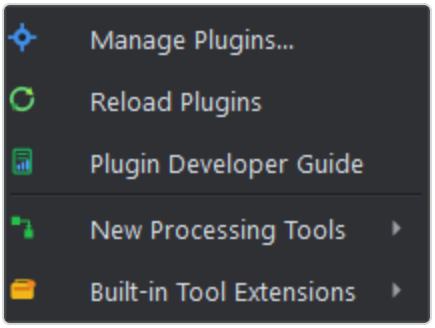
ALS Area-Based Modeling & Mapping...	Relate plot data to LiDAR metrics, fit and validate models, map them and report.
Voxel-based Modeling...	Model forest attributes from voxel metrics.

Tools › Virtual Forest



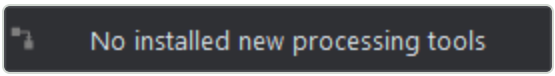
Create Virtual Forest	Place a 3D tree model on every detected tree (with optional birds).
Save Virtual Forest Scene...	Saves the virtual forest with its terrain, trees, 3D models, look and camera as one .silvascene file that SilvaLiDAR Air opens again
Open Virtual Forest Scene...	Opens a .silvascene file: the terrain, the trees and their models, ready to view and walk in

Plugins



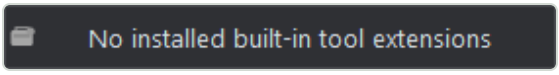
Manage Plugins...	List, install and remove plugins.
Reload Plugins	Scan the plugin folders again.
Plugin Developer Guide	How to write new processing tools.
New Processing Tools ▸	Tools added by plugins.
Built-in Tool Extensions ▸	New methods added to built-in tools.

Plugins › New Processing Tools



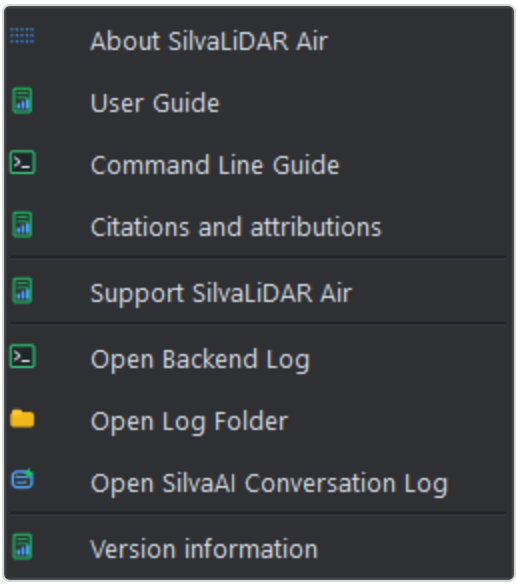
No installed new processing tools	

Plugins › Built-in Tool Extensions



No installed built-in tool extensions	

Help



About SilvaLiDAR Air	Version, licence and credits.
User Guide	The full User Guide.
Command Line Guide	The guide to SilvaLiDARAirCLI.exe.
Citations and attributions	The methods behind each tool and how to cite them.
Support SilvaLiDAR Air	Free use, donations and sponsors, and how to contact the SilvaLab team

Open Backend Log	The processing log of this session.
Open Log Folder	The folder with all logs (for support).
Open SilvaAI Conversation Log	The record of SilvaAI conversations.
Version information	Version, build and libraries.

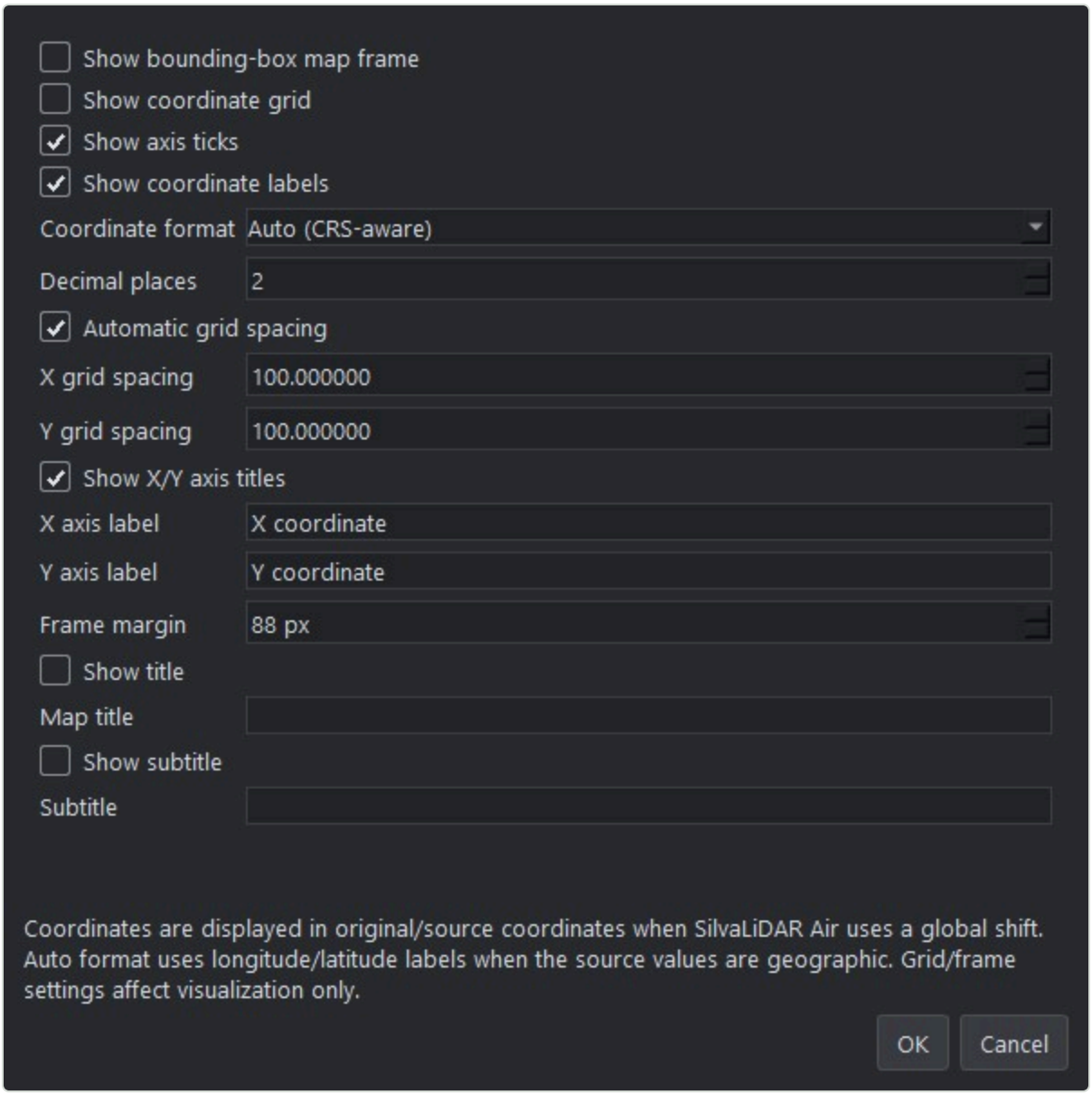
The 2D Scene

2D/3D View › 2D Map

The map view of all layers: point clouds (coloured by RGB, elevation, intensity, class or tree), rasters and vectors. The wheel zooms and dragging pans. The forester button and the compass sit at the bottom right.



The 2D Scene with the point cloud, the scale bar, the forester and the compass.



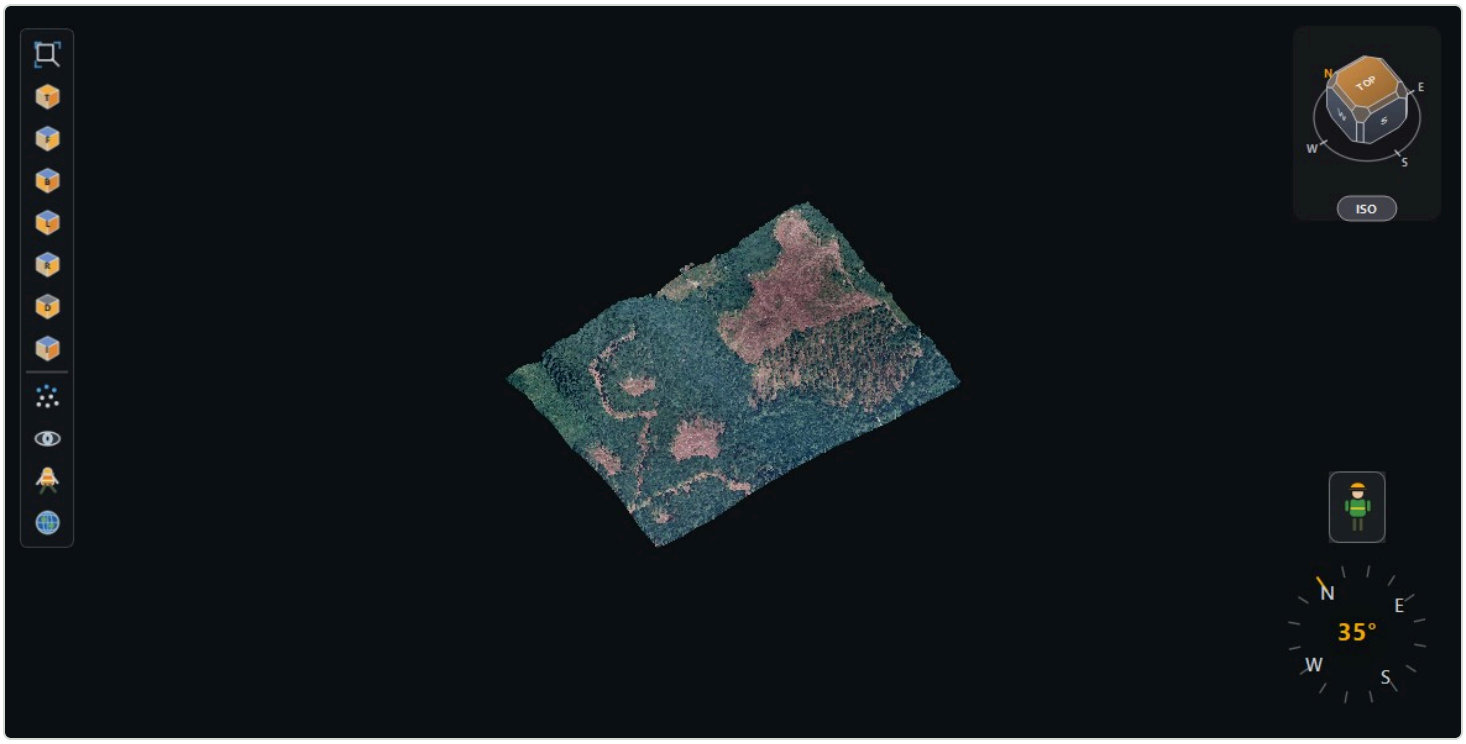
View › 2D Map Frame & Grid: coordinate grid, ticks, labels and titles.

- View › 2D Map Frame / Grid adds a frame, a coordinate grid and titles for figures.

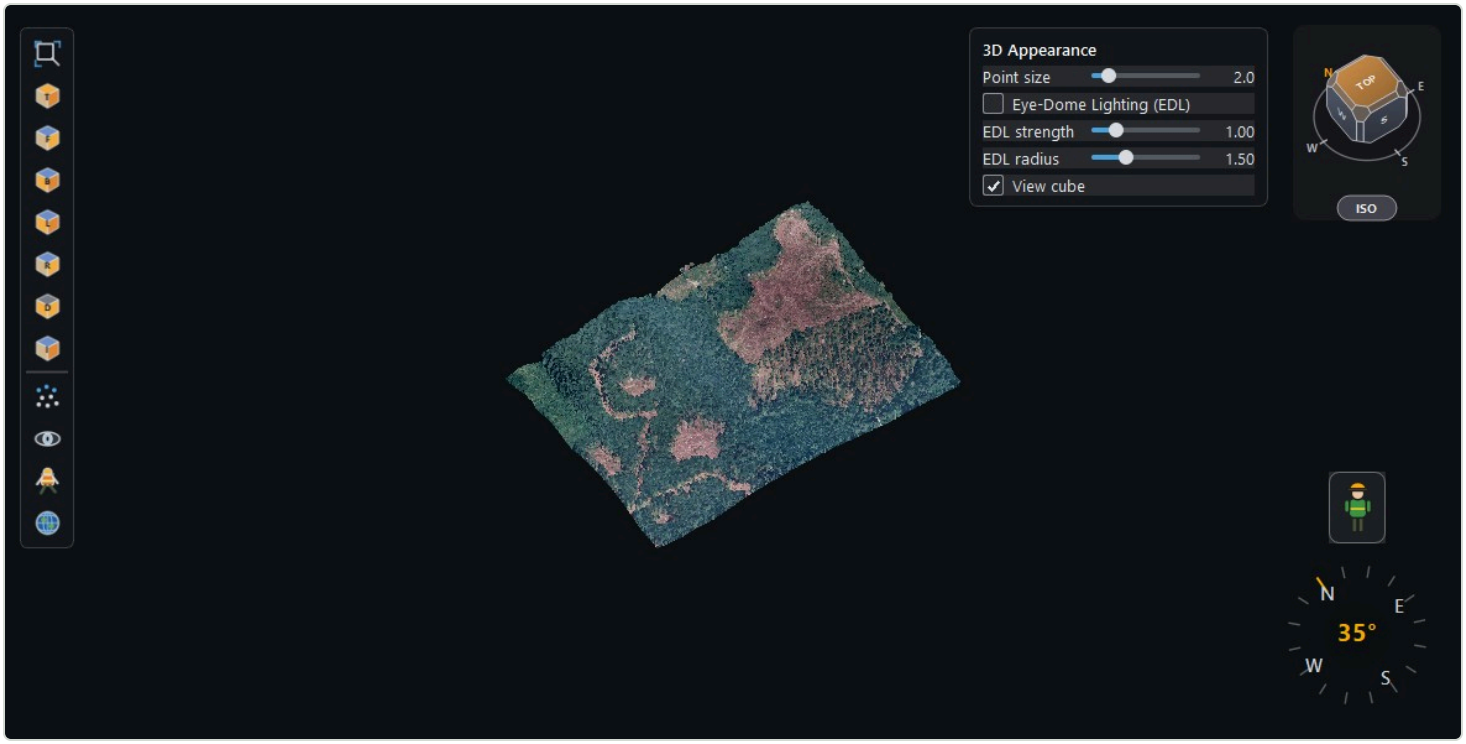
The 3D Scene

2D/3D View › 3D View

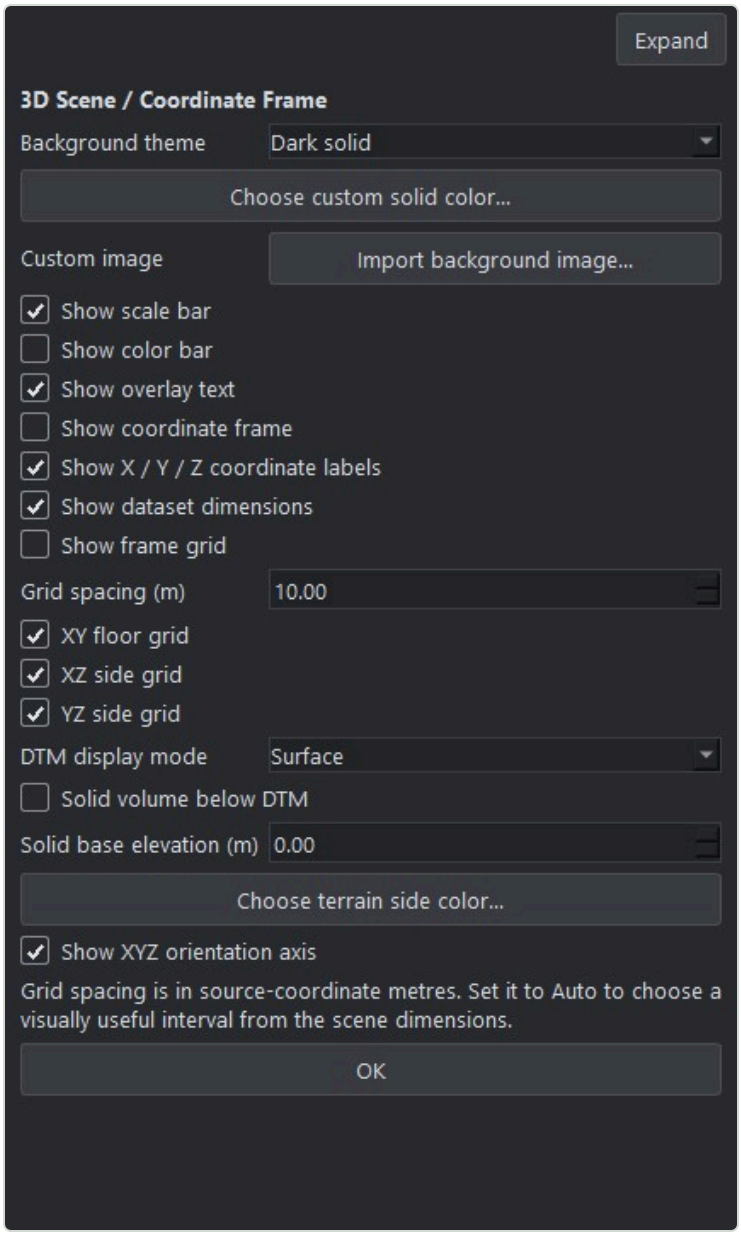
The point cloud and the products in 3D. Drag to orbit, Shift-drag to pan, the wheel to zoom. The toolbar on the left sets standard views and display options, the view cube turns the camera to any side, and the compass shows the heading.



The 3D Scene with its controls on the left and the view cube.



The 3D appearance panel.



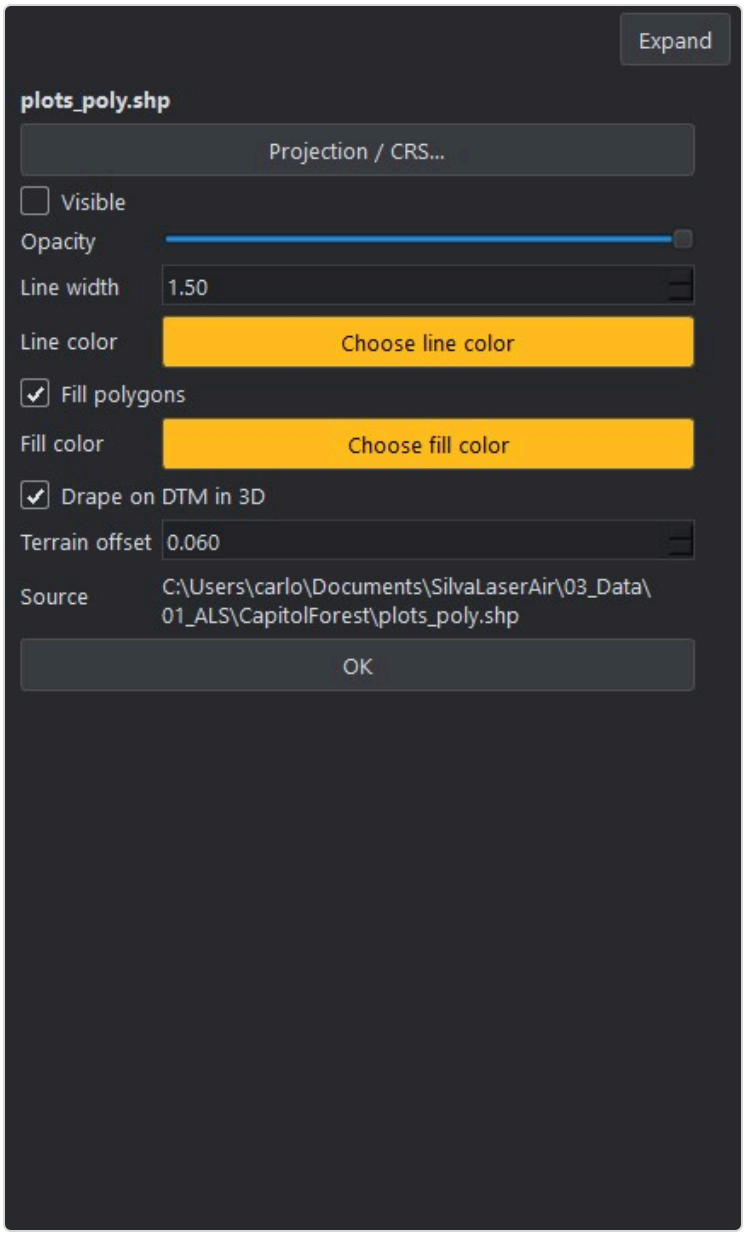
3D Scene properties: background, frame, grids and the DTM surface.

- Eye-Dome Lighting shades the points by depth so the relief reads more clearly.
- View › 3D Scene Properties sets the background, lighting, axes and scale bar.

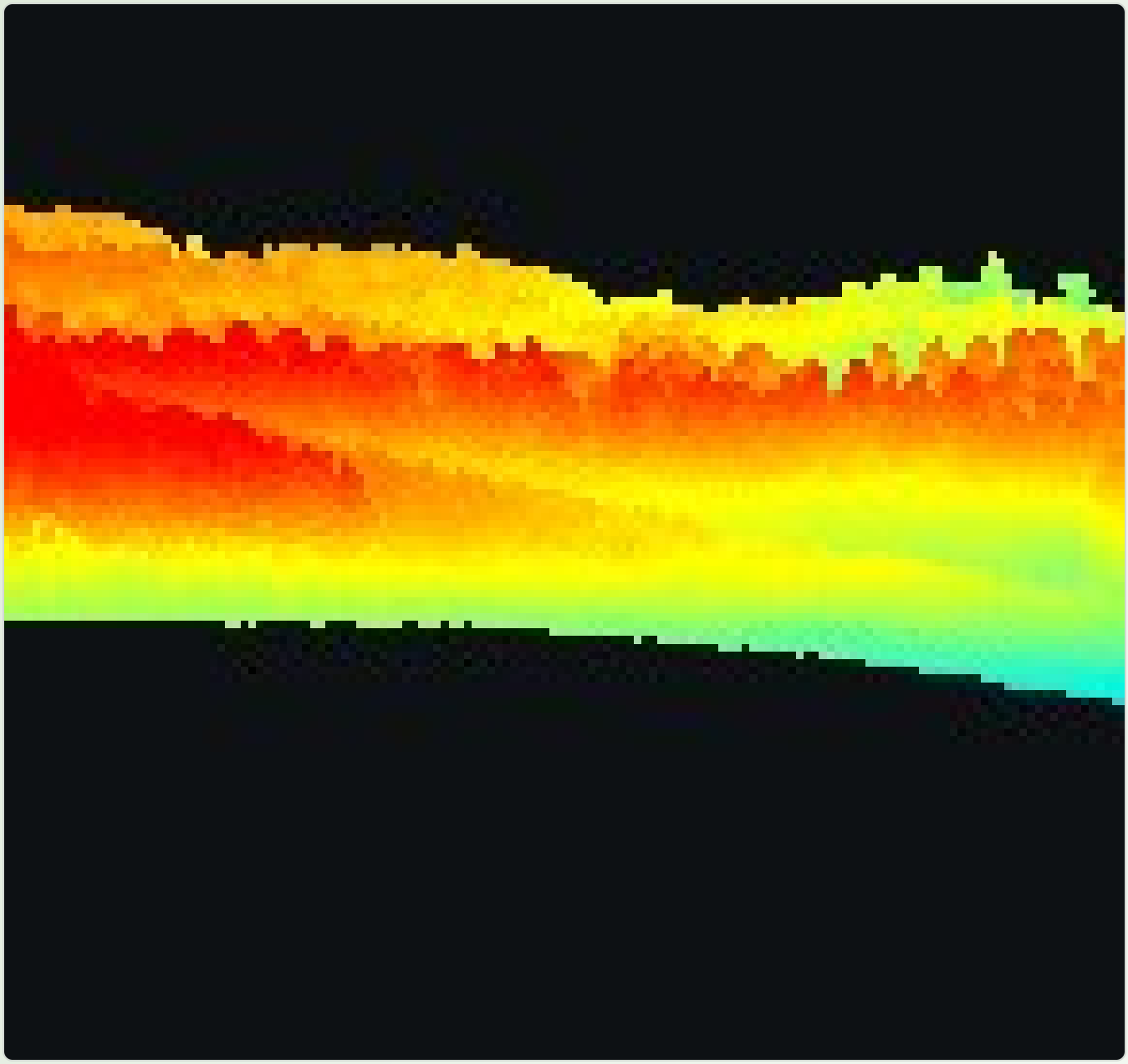
Layers and their Properties

Data panel › right-click a layer › Properties

Each layer has a Properties window: colour mode and palette, point size, filters by class or height, opacity, how a raster is drawn and draped in 3D, and how a vector is styled.



Properties of a vector layer.



PART 2

Reference

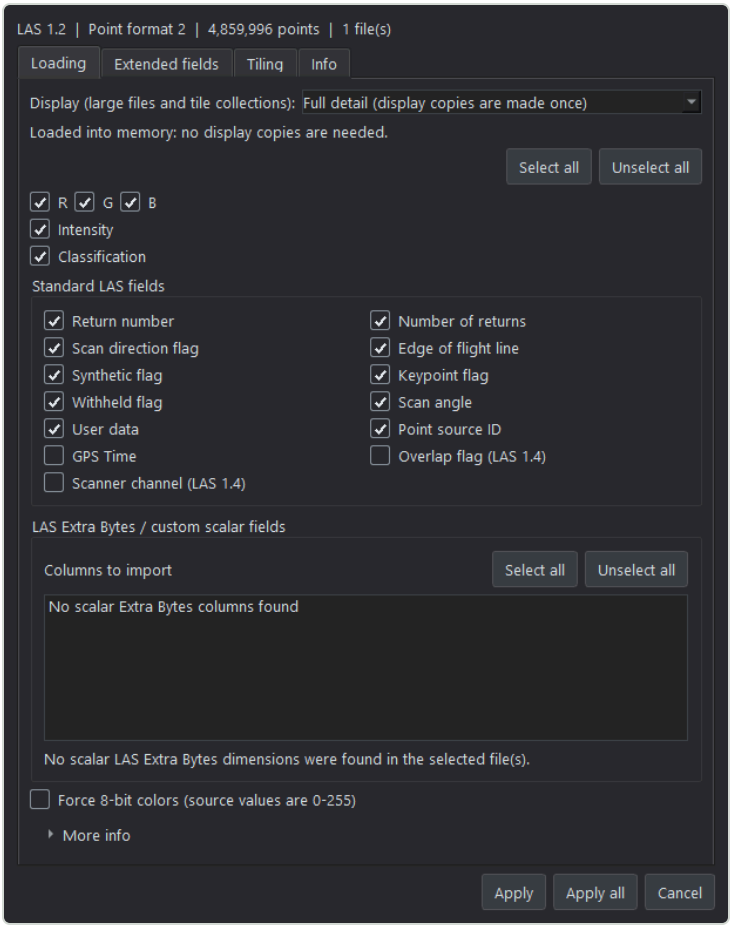
Data in and out, exploring the data, every processing tool with its window and its result on the example data, workflows, the assistant and the command line.

Data in and out

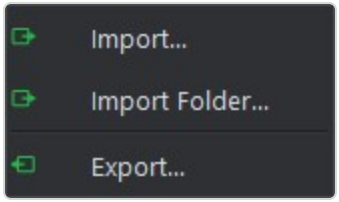
Import and export

Import/Export button · File menu

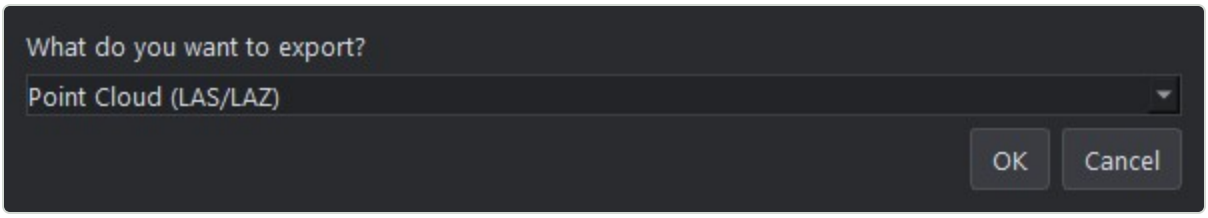
Import opens LAS/LAZ/COPC point clouds, rasters and vectors. For point clouds you choose first how large data are displayed (Full detail, Preview only or Bounding boxes only, with the space the display copies will take), then the attributes to keep and whether to load the points (files that fit in memory) or open a streamed collection (very large files or many files: points stay on disk and only what you look at is read). Data open in the 3D Scene. Export writes point clouds, rasters, vectors, tables and 3D products.



Open LAS File: how large data are displayed, then the attributes to keep.



The Import/Export menu.

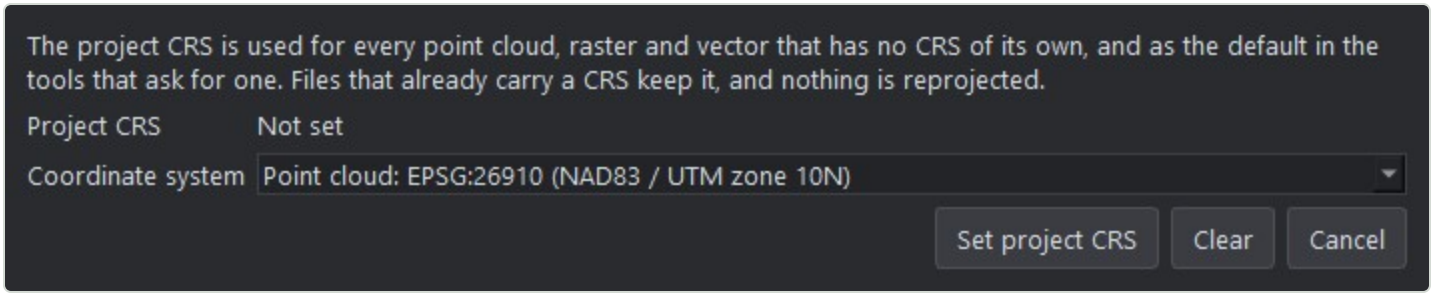


The Export dialog.

Coordinate systems

File › Project CRS · Tools › Raster/Vector › Assign CRS / Reproject

Most LAS/LAZ files carry their CRS in the header. When one does not, set the Project CRS (used by every layer without one) or assign a CRS to the layer. Assign only declares the CRS; Reproject transforms the data.



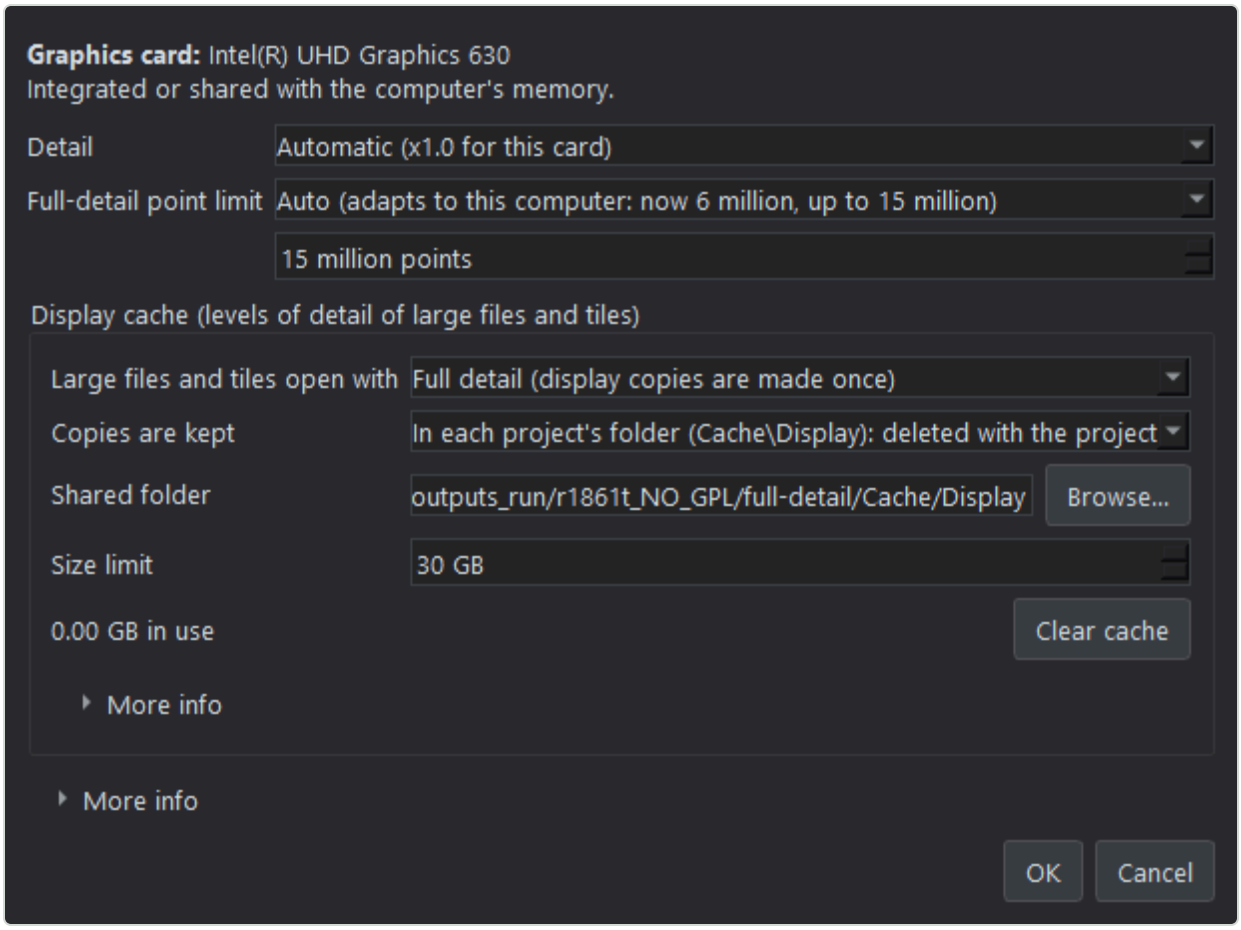
File › Project CRS.

- The status bar always shows the CRS in use.

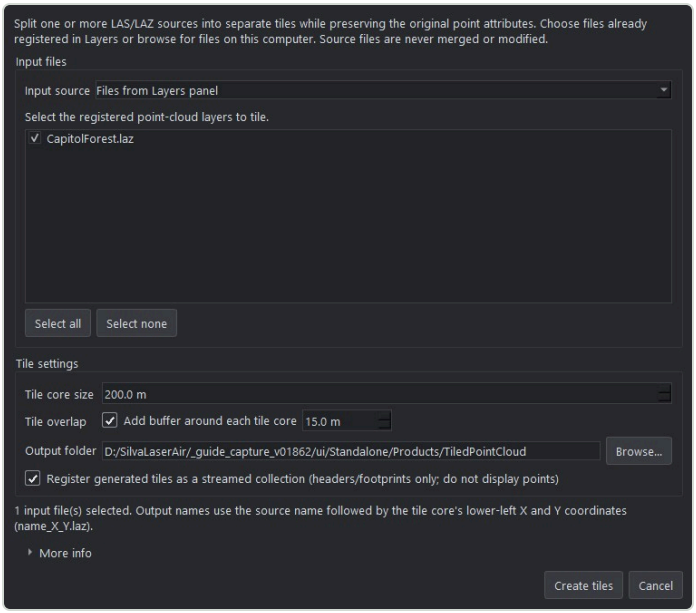
Large datasets and tiles

View › Large Dataset / Streaming · Tools › Point Cloud › Create tiles

Files of hundreds of millions of points open without loading everything. With Display: Full detail a compressed display copy of each file (COPC, with its levels of detail) is made once, in the project's Cache\Display, and zooming reads only the visible detail; Preview only reads an even sample from the files; Bounding boxes only reads no point for display and draws each file's box and footprint. The disk always keeps 4 GB free, and a note and a warning tell how much space the copies take. View › 3D Display Detail sets the full-detail point limit (Auto follows the computer), where the copies are kept and their size limit. Processing tools always read the original files. Create tiles splits sources into tiles that keep every attribute, with an optional overlap buffer.



View › 3D Display Detail: the full-detail point limit, the display copies and where they are kept; the long explanations fold under More info.



Create tiles LAS/LAZ.

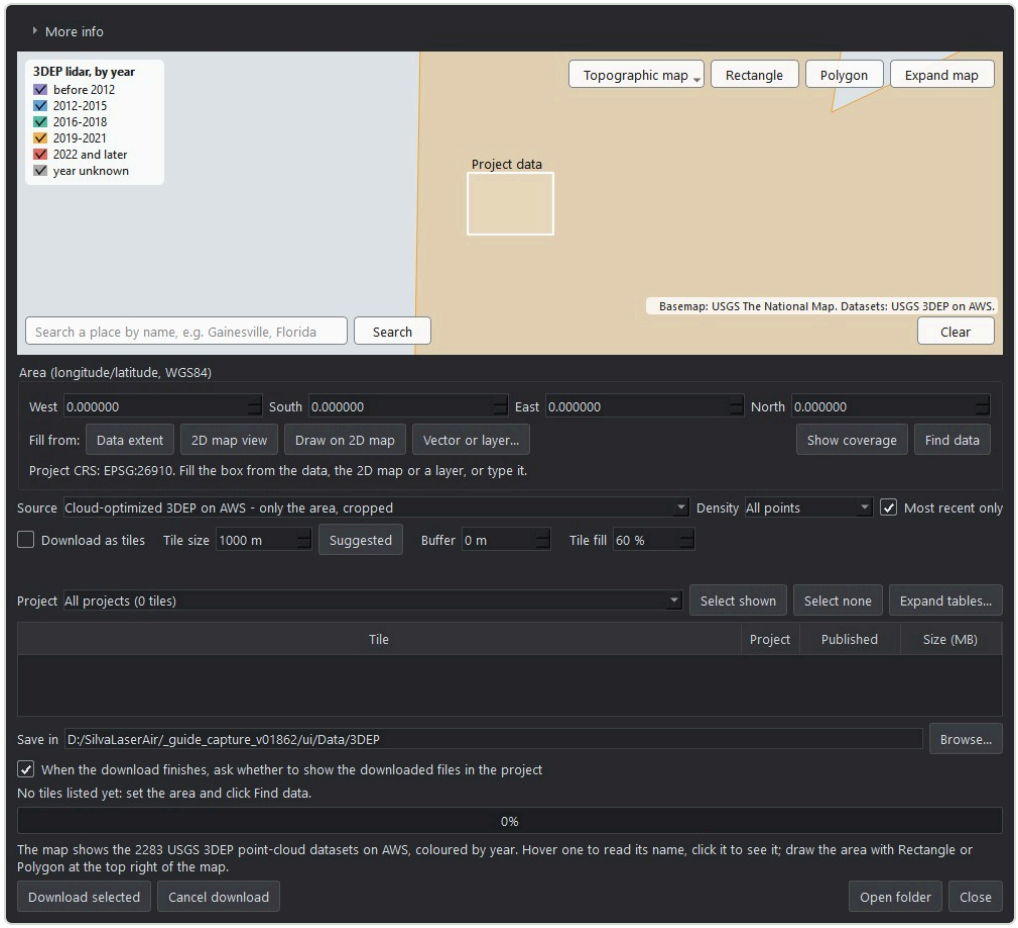
Command line

```
SilvaLiDARAirCLI.exe --tool build-lax --input C:\SilvaLiDARAirExercise\01_Sites\01_CapitolStateForestWA\01_LAZ\CapitolForest.laz
```

Download USGS 3DEP LiDAR

3DEP LiDAR button

Finds and downloads the free airborne LiDAR of the USGS 3D Elevation Program for an area of the United States: draw the area on the map of available data, Find tiles, tick datasets and Download selected. The cloud-optimized source gives only the points of your area, at the density you choose, reprojected to the project CRS; large areas download as tiles ready for Catalog.



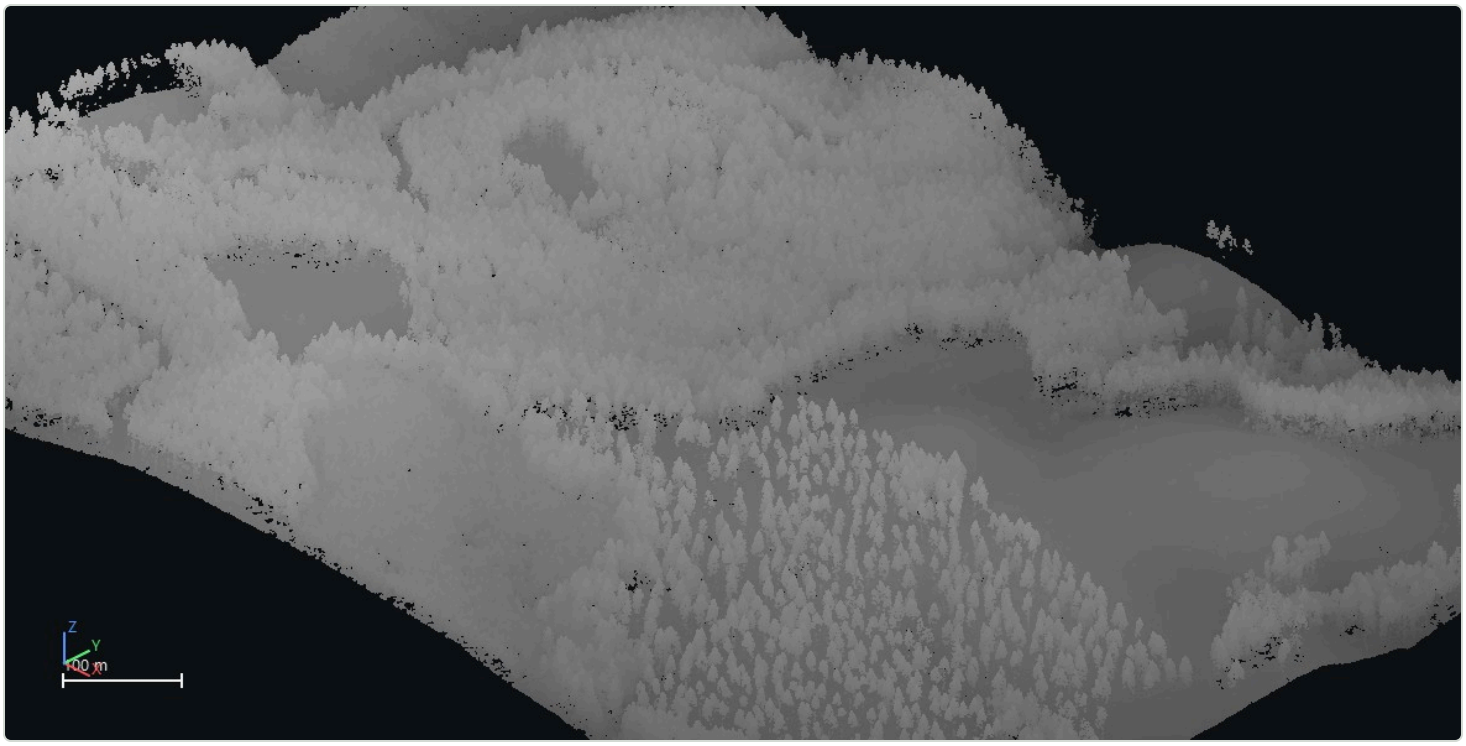
The 3DEP LiDAR window.

- Credit the U.S. Geological Survey 3D Elevation Program when you publish results.

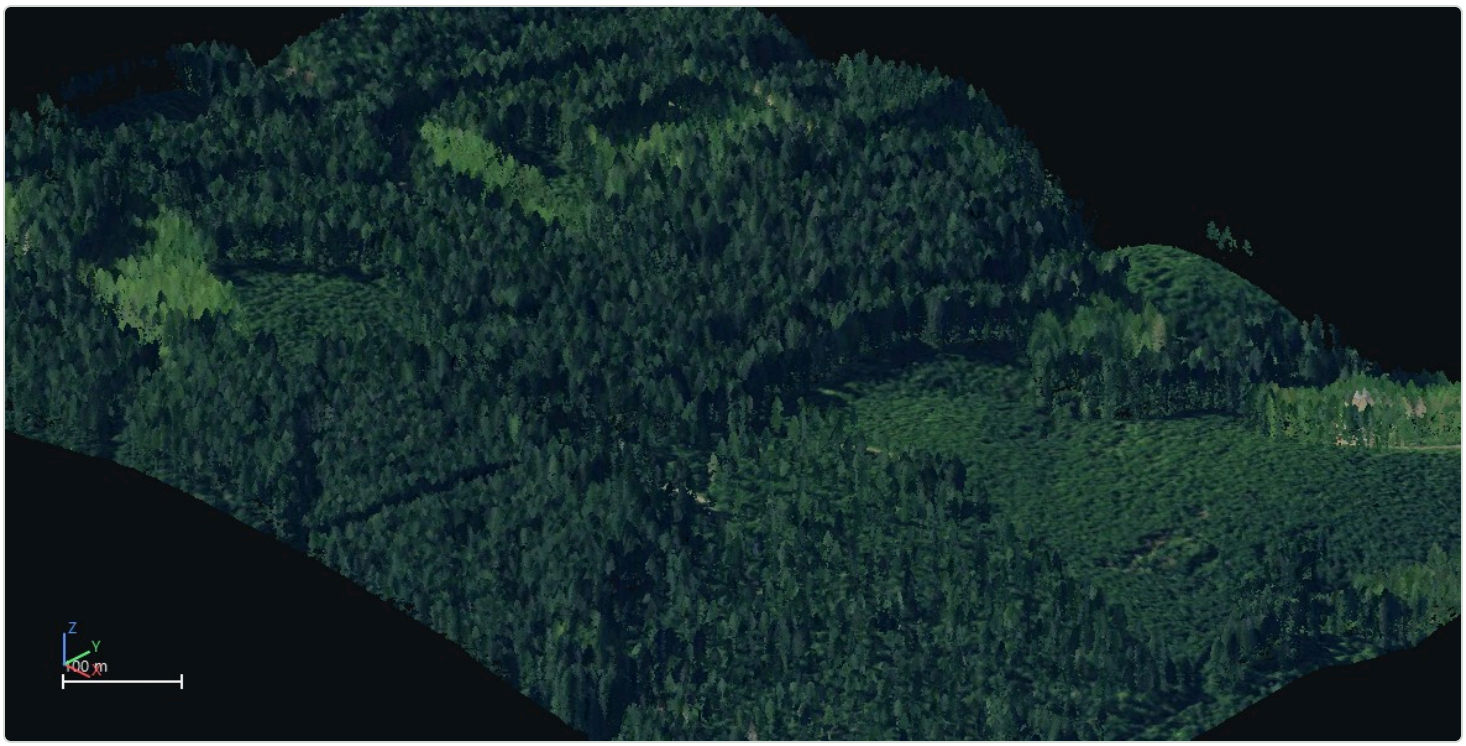
Colorize

Tools › Point Cloud › Colorize LAS/LAZ

Samples three bands of an orthophoto, of Earth imagery added to the project or of any raster at every point and gives the loaded point cloud those colours at once; tick the copy option to also write colorized LAS/LAZ files. The original files are never changed.



Before Colorize: a point cloud with no colours of its own.



After Colorize with the NAIP imagery of the project: every point takes the colour of the image under it.

Earth Imagery

Earth Imagery button

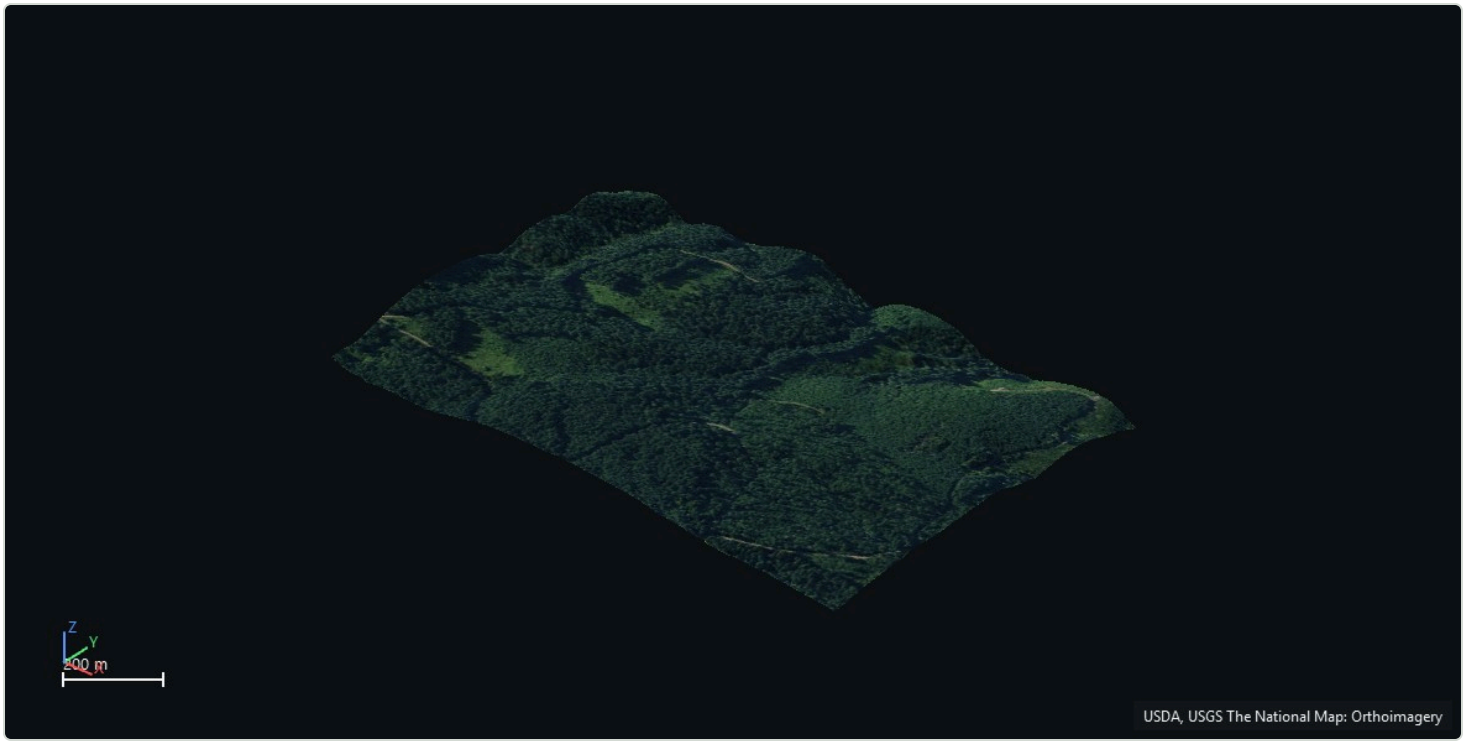
A live basemap behind the 2D map, or imagery clipped to the project that can be draped over the DTM in 3D. Built-in providers: USGS NAIP, USGS topographic map and orthoimagery, Mapbox (your own token), or a local GeoTIFF/COG/JP2. Any other service you are authorized to use is added as Custom XYZ or TMS tiles by pasting its tile URL.



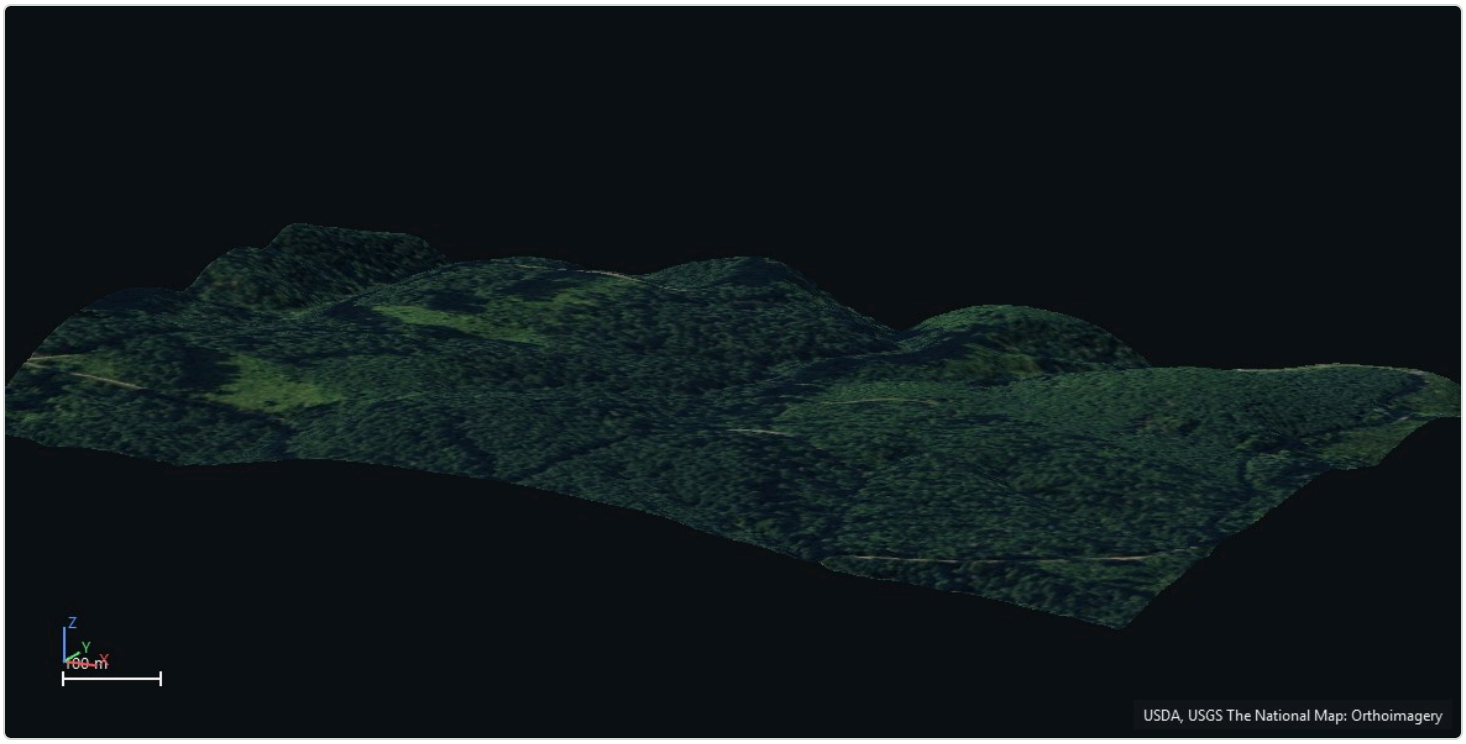
A Custom XYZ source clipped to the project: the USGS topographic map.



USGS NAIP imagery clipped to the project extent, on the 2D map.



The same imagery draped on the DTM in 3D: roads, harvest units and stands on the real relief.



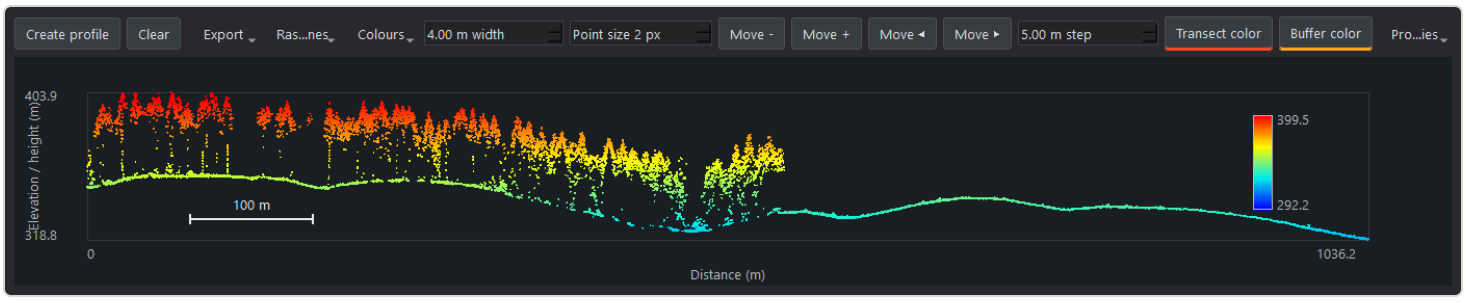
Draped imagery closer and lower: the forest edge over the slope.

Exploring the data

Profiles

Profile button

A vertical slice through the cloud along a line drawn on the 2D map, with its own panel for width, point size, colours and export.



A profile coloured by elevation: the ground rising across the stand and the crowns above it.

Measure

Measure button

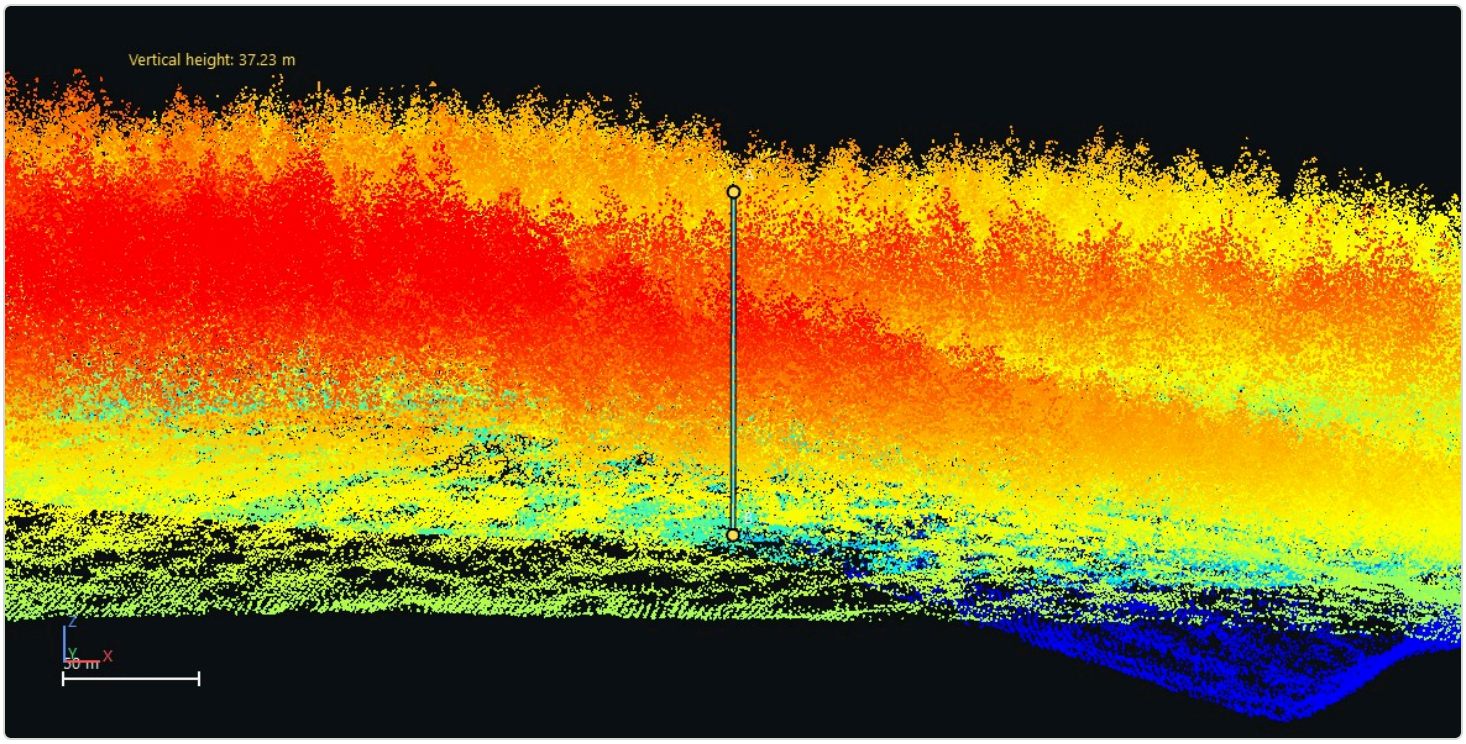
Horizontal distance and area on the map; 3D distance, vertical height, slope and point query on the 3D points; angles from three points.



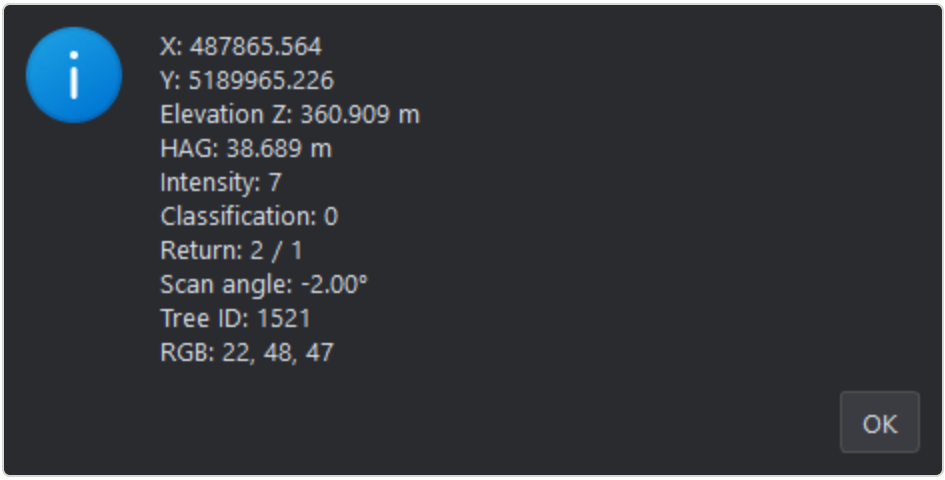
2D Horizontal Distance: two clicks on the map give the distance between them.



2D Area: a polygon clicked on the map gives its area and perimeter.



Vertical Height on the points in 3D: a click on a tree top and one on the ground below it give the tree's height.

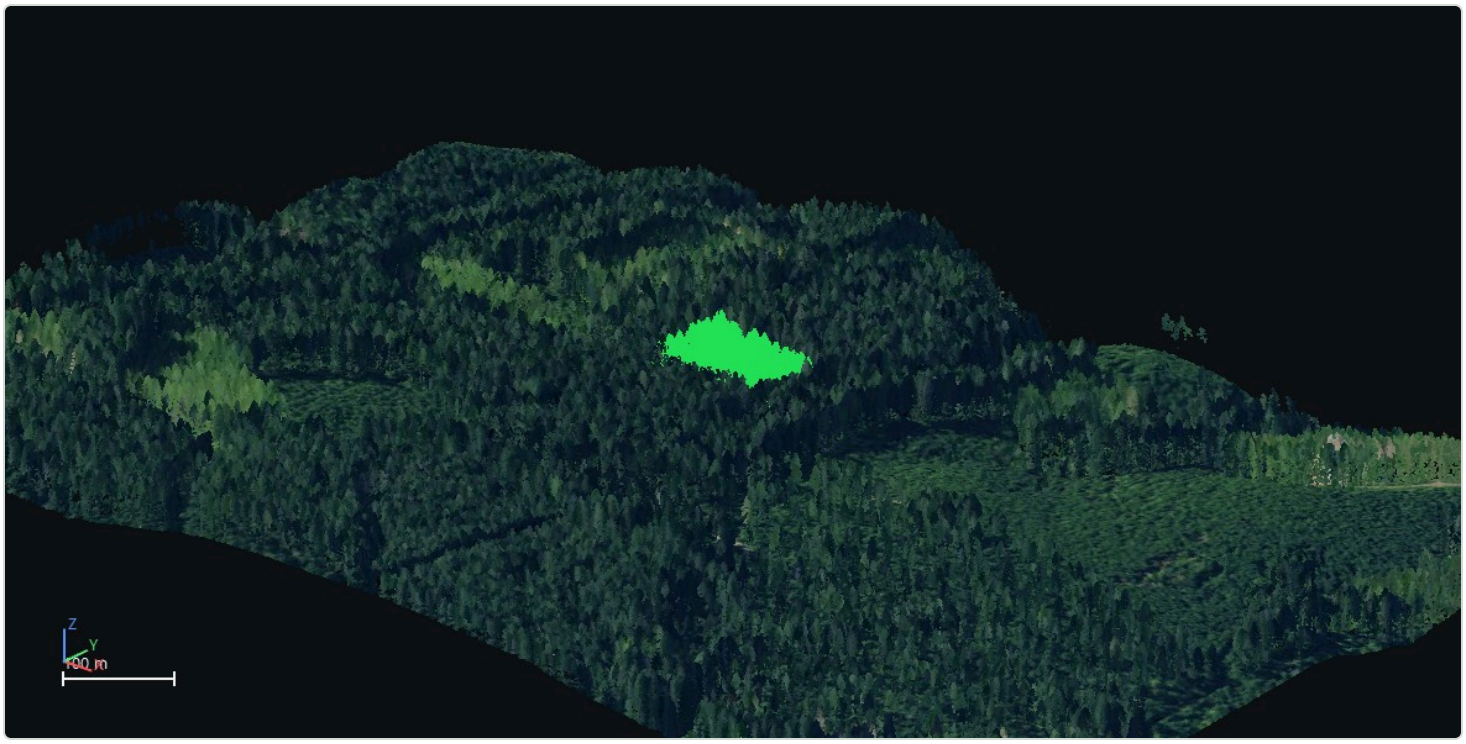


Point query: one click on a point shows its coordinates, elevation, height above ground, intensity, class, return and colour.

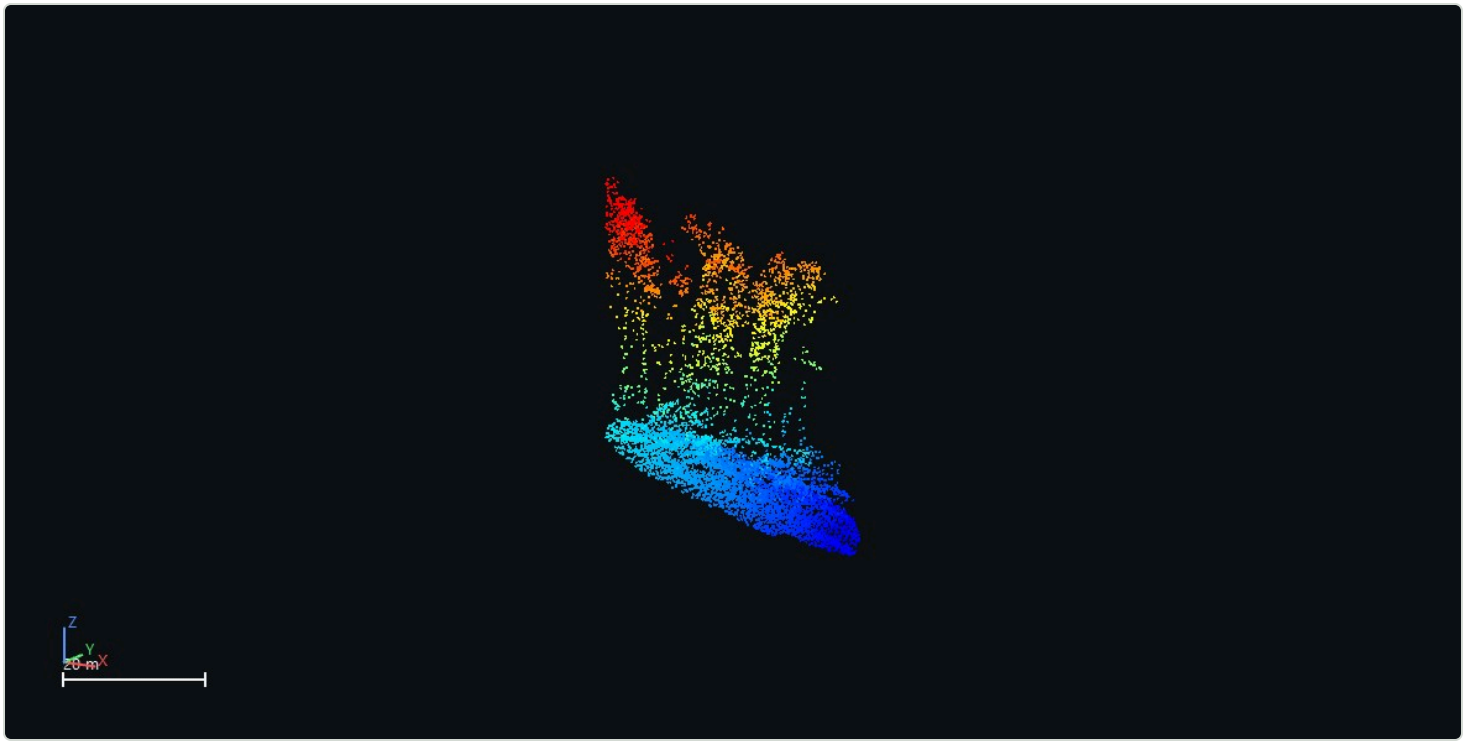
Quick Clip

Quick Clip button

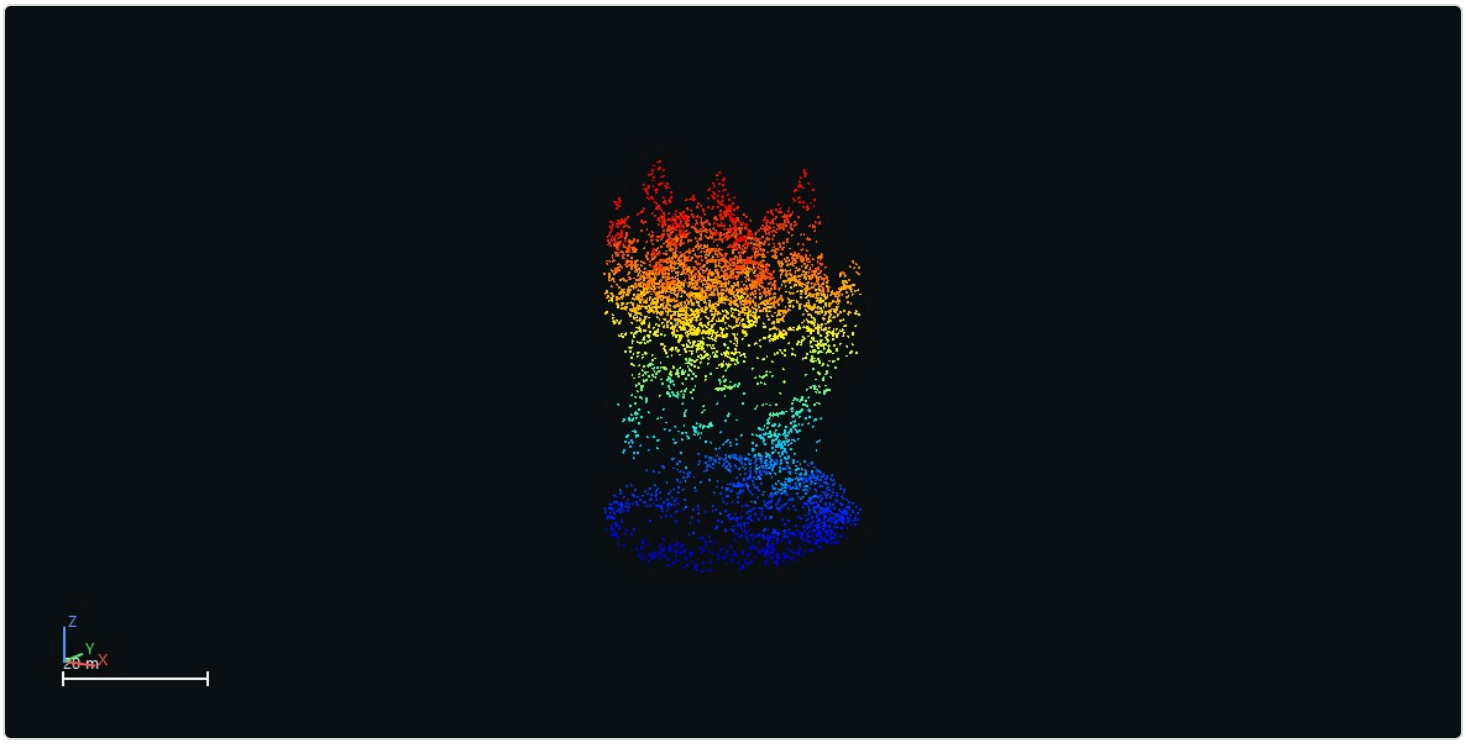
Cut out by hand the part of the cloud you draw, with a polygon or box, on the map or in the 3D scene, and keep it (IN) or remove it (OUT), at full resolution. The files the drawing meets are read in parallel and the clip is written on several threads (a 46 million point clip of a terrestrial scan in about 25 s), with the window responding and Cancel working. A floating bar applies or cancels the preview; a kept clip can be saved as LAS/LAZ. To clip by plot polygons or a shapefile, use Tools › Point Cloud › Clip Point Cloud.



Clip IN box: the selection previewed in the 3D Scene before it is applied.



A plot clip in 3D (written by Clip Point Cloud with the plot polygons): the plot's trees from the side.

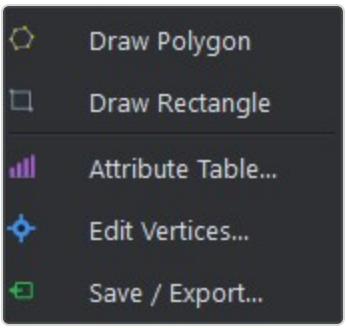


Another plot clip in 3D.

Vector editing

Vector Editing button

Draw polygons and rectangles, edit their attributes and vertices, and save them as GeoPackage, GeoJSON or Shapefile.



The Vector Editing menu.

Snapshot

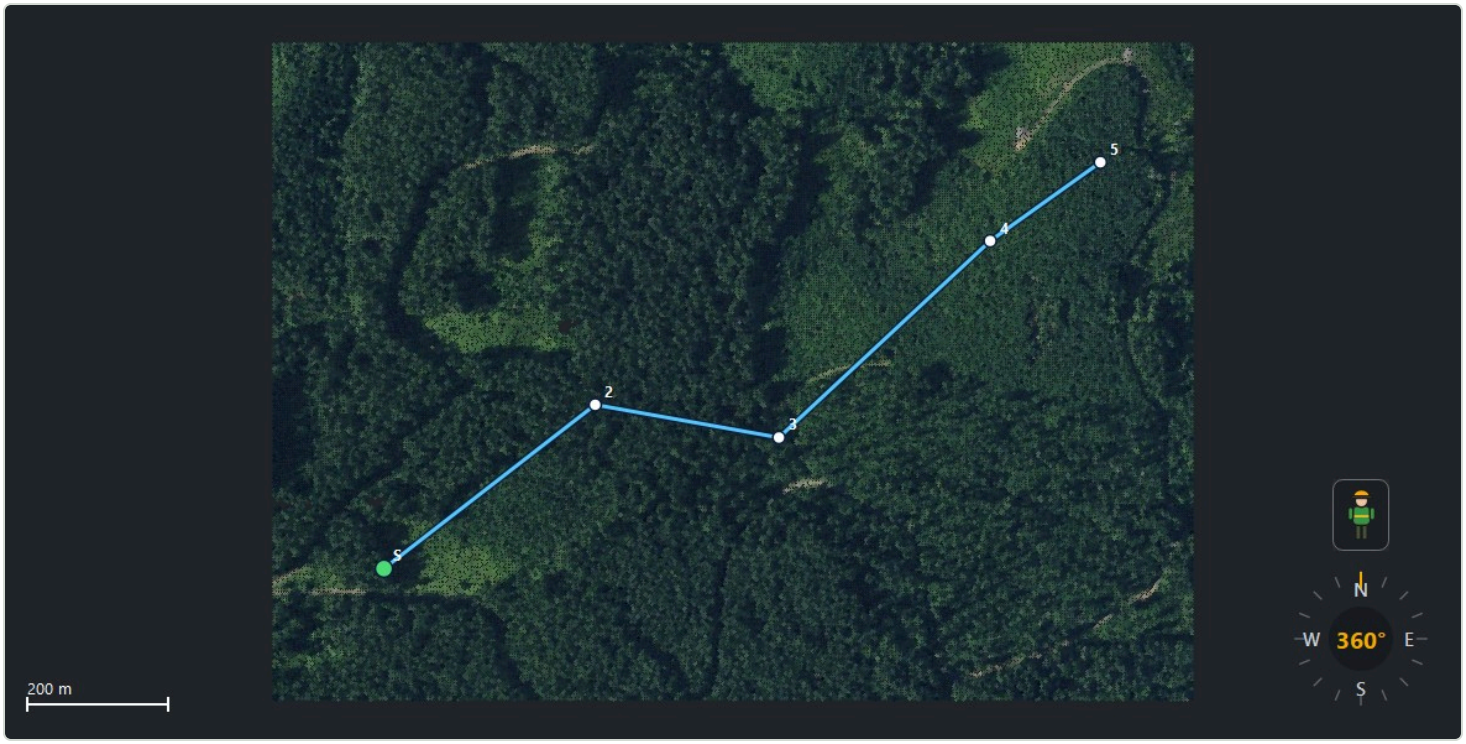
Snapshot button

Save the current 2D, 3D or split view as an image.

Animations

Animation button

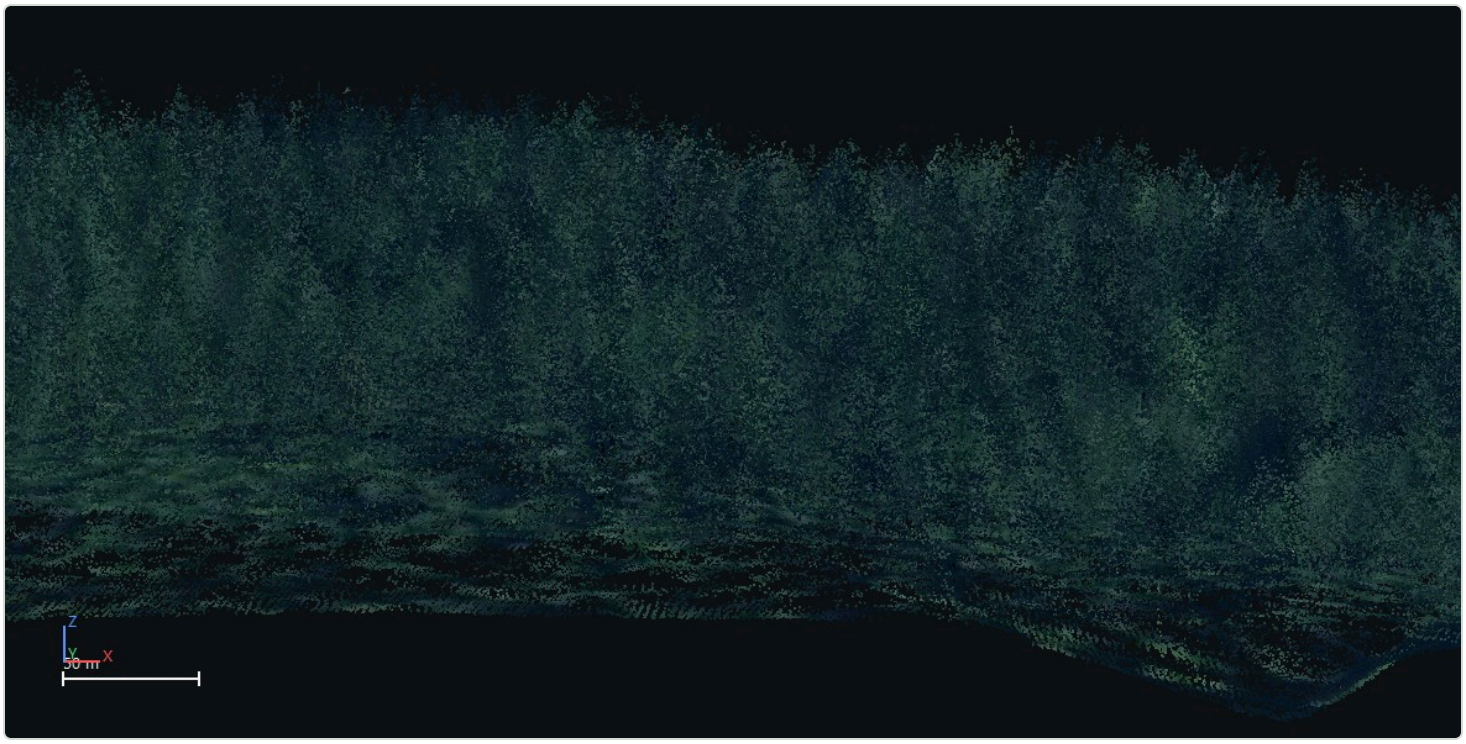
Spin turns the 3D view around a centre; Flight Through flies the camera through captured views or along a path drawn on the map. Both export MP4 videos.



Flight Through: a path drawn on the 2D map, from the first click to the double-click.



The path in the Flight Through window: the camera height along the terrain and canopy, and the speed.



A frame of the flight: the camera follows the path over the stand.

Walk with the forester

Forester button on the 2D map · Walk button in 3D

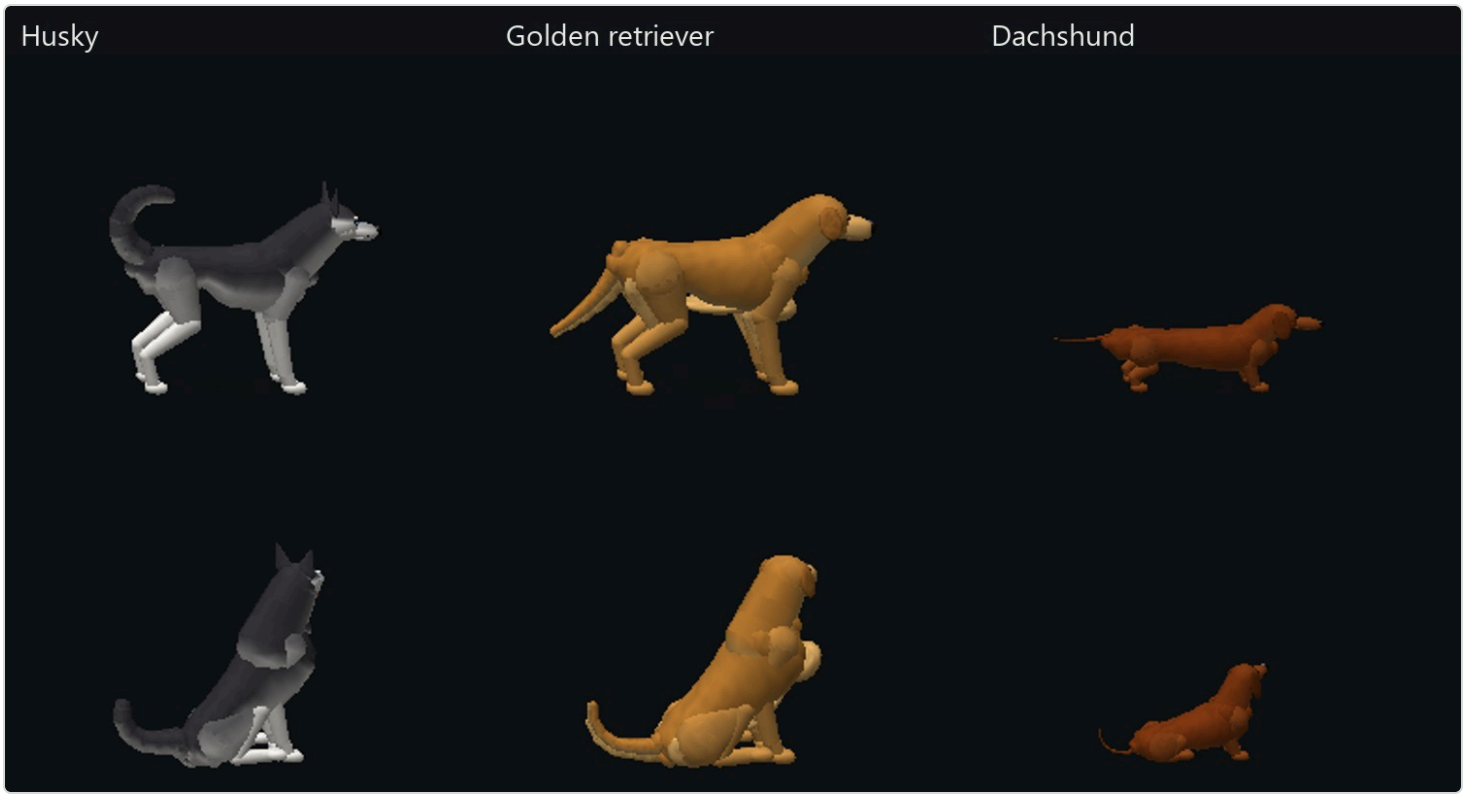
Walk through the stand at eye height. The forester follows the ground, cannot walk through stems, and can be seen from behind or through his eyes. W A S D move, Shift runs, Space jumps, drag to look around. Under the canopy a click on a stem selects that tree and opens its attribute card. Right-click › Walk mode: ride a bicycle, an ATV or a motorcycle, bring a dog (husky, golden retriever or dachshund) and throw it a treat (T), fell the selected tree with the chainsaw (C; Ctrl+Z stands the last one up again), fly the drone (F; E and Q climb and descend in fine steps), and choose the forester’s body, skin tone, eyes, face shape, hair, glasses and beard.



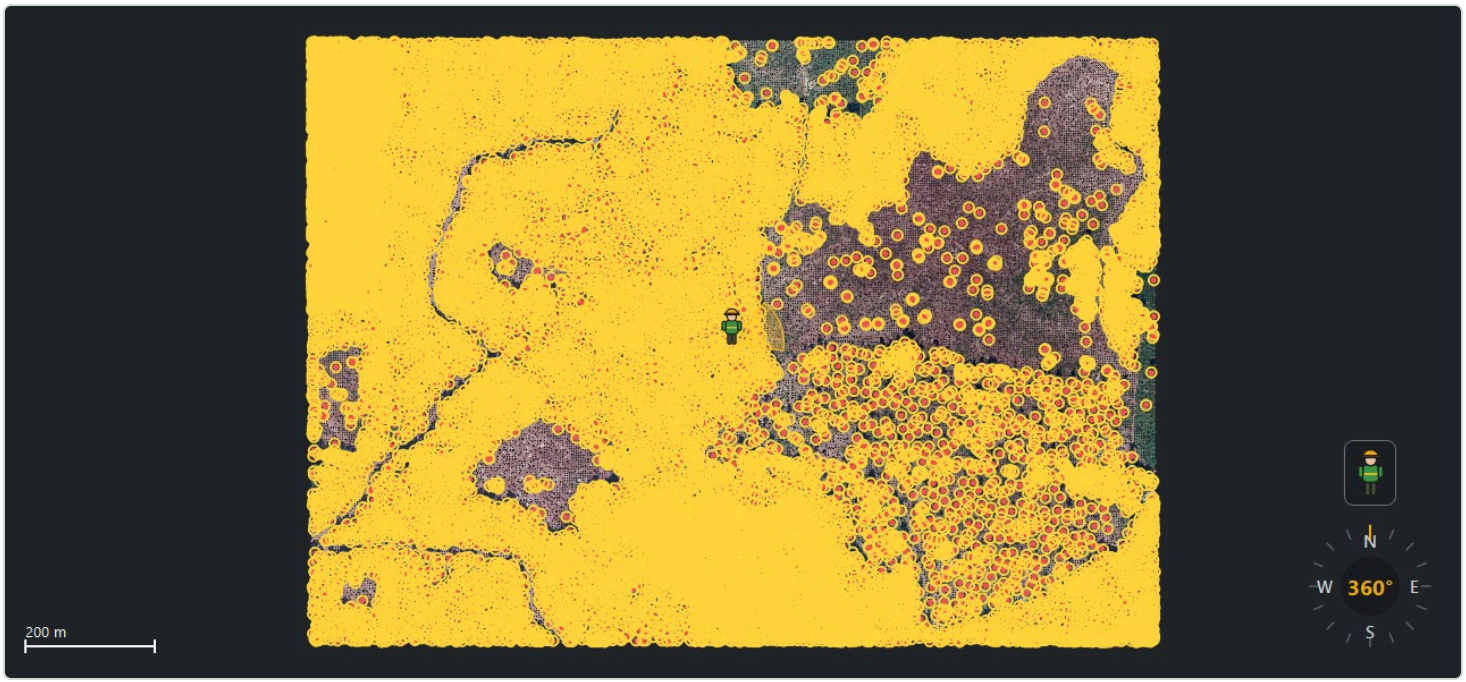
The forester in the stand.



The forester as you choose: face shape, eyes, skin tone, hair colour and style, glasses and beard.



The dog breeds, standing and sitting: husky, golden retriever and dachshund.



The 2D map marks where the forester stands.

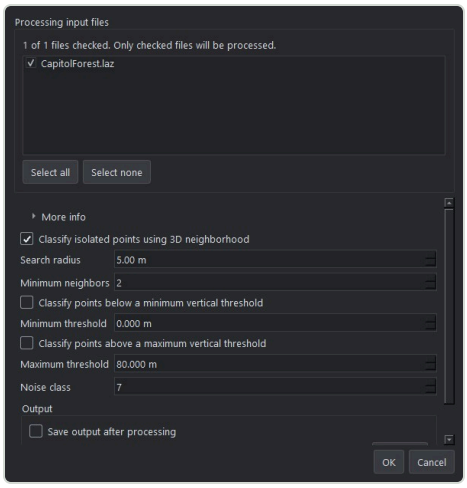
Processing tools

Every processing tool of the Tools menu, with its window, its result on the example data and, where there is one, the same step from the command line.

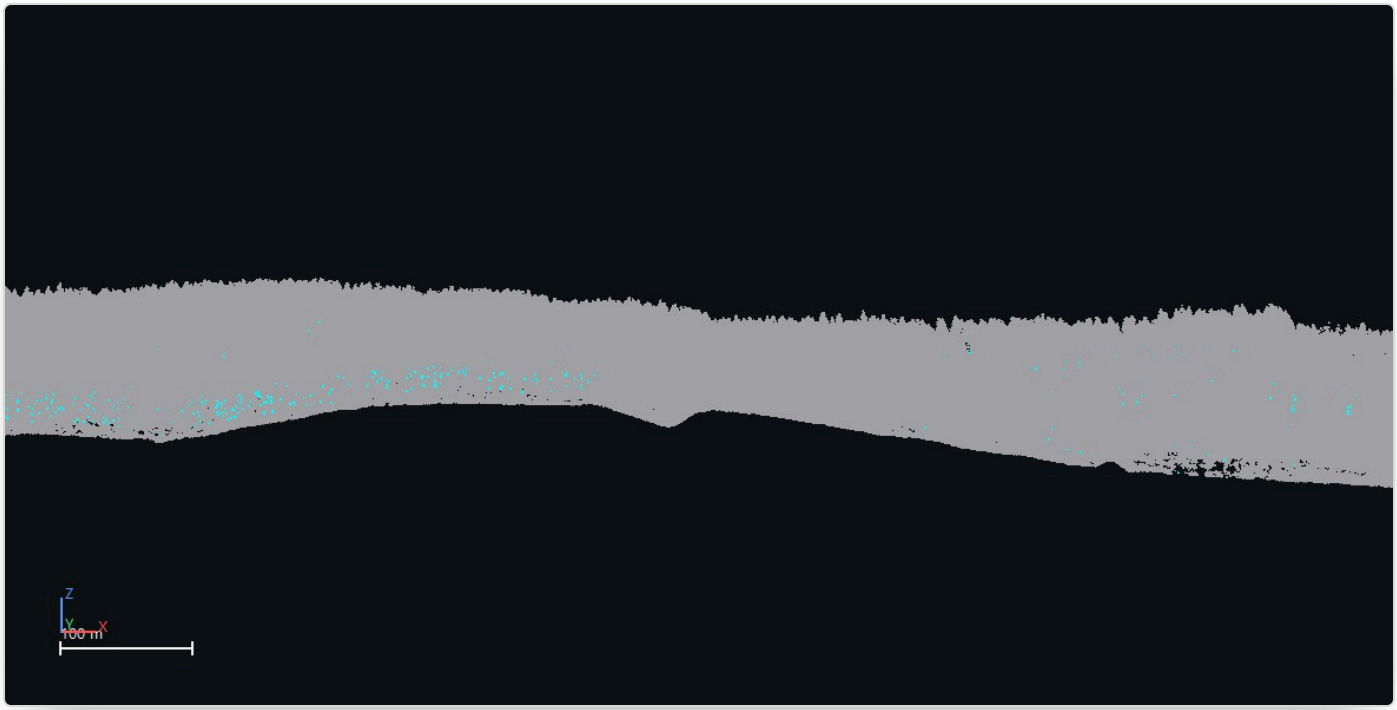
Noise Removal

Tools › Point Cloud › Noise Removal

Flags isolated points (birds, atmospheric returns, stray returns below the ground) as class 7 before any other step. A point is noise when it has fewer than 2 other points within the search radius (5 m by default): a smaller radius flags more points. The right radius depends on your data: Exercise 5, Part 1 compares 1 to 8 m on the example cloud, so you can choose.



The window.



The result on the example data.

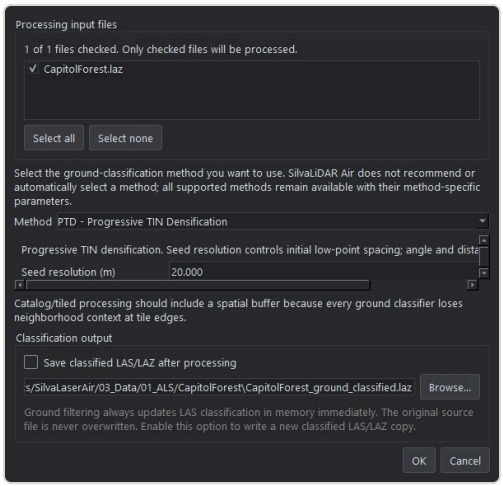
Ground Filtering

Tools › Terrain › Ground Filtering

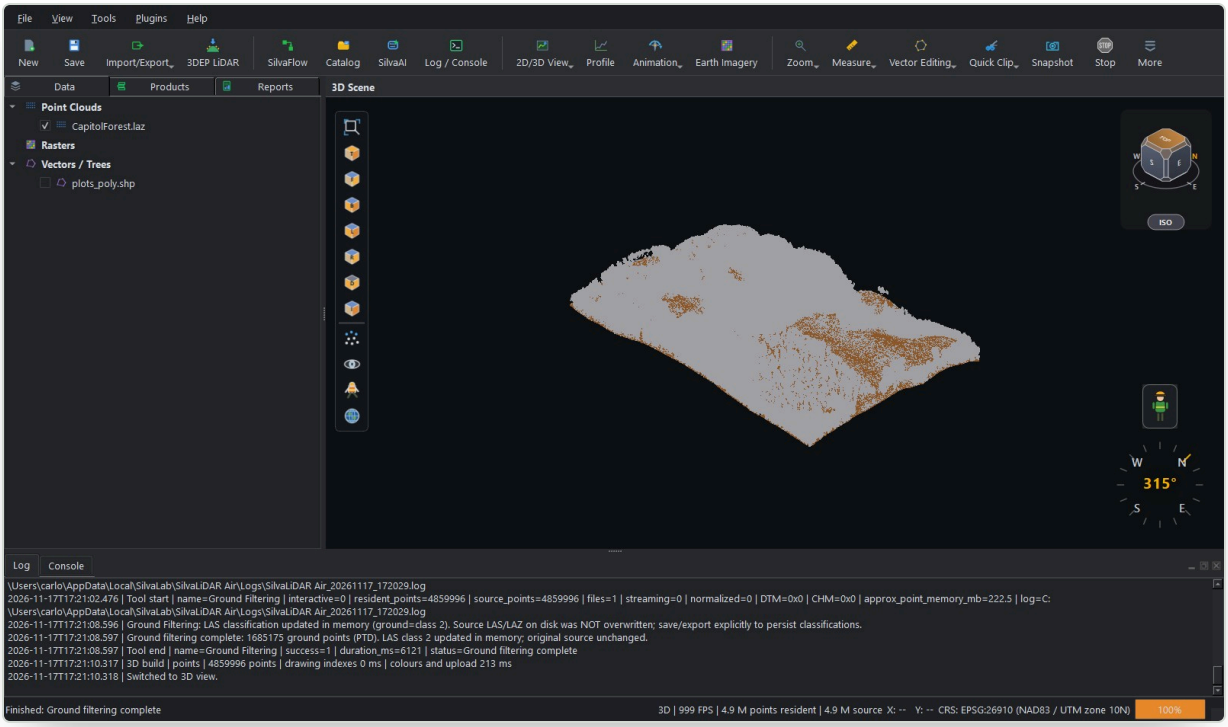
Separates ground returns (LAS class 2) from vegetation. PTD is the default; MCC, CSF, PMF, SMRF, WLS, MV-HCS and AMT are available. Ground is searched among the last and single returns.

Command line

```
SilvaLiDARAirCLI.exe --tool ground --input C:\SilvaLiDARAirExercise\01_Sites\01_CapitolStateForestWA\01_LAZ\CapitolForest.laz --output C:\SilvaLiDARAirExercise\03_Projects\cli_out\ground.laz --method ptd
```



The window.



The result on the example data.

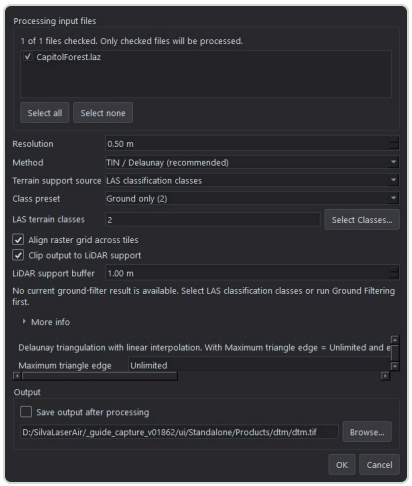
DTM

Tools › Terrain › DTM

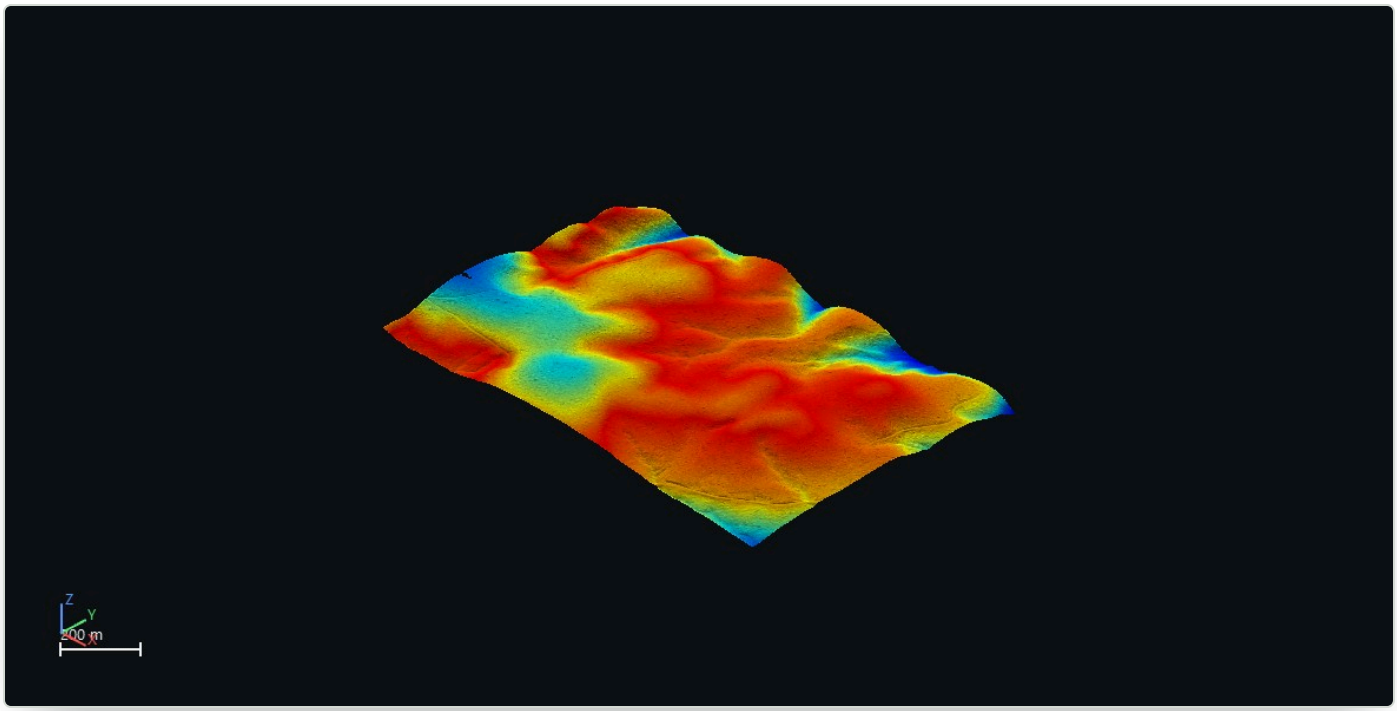
Interpolates the bare-earth terrain raster from the ground returns (TIN, KNN-IDW or Kriging; 0.5 m by default).

Command line

```
SilvaLiDARAirCLI.exe --tool dtm --input C:\SilvaLiDARAirExercise\03_Projects\cli_out\ground.laz --output C:\SilvaLiDARAirExercise\03_Projects\cli_out\dtm.tif --method tin --resolution 1
```



The window.



The result on the example data.

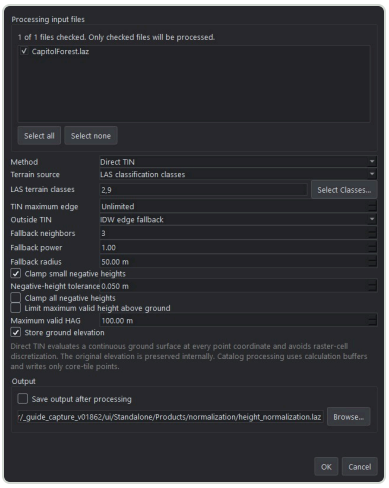
Height Normalization

Tools › Terrain › Height Normalization

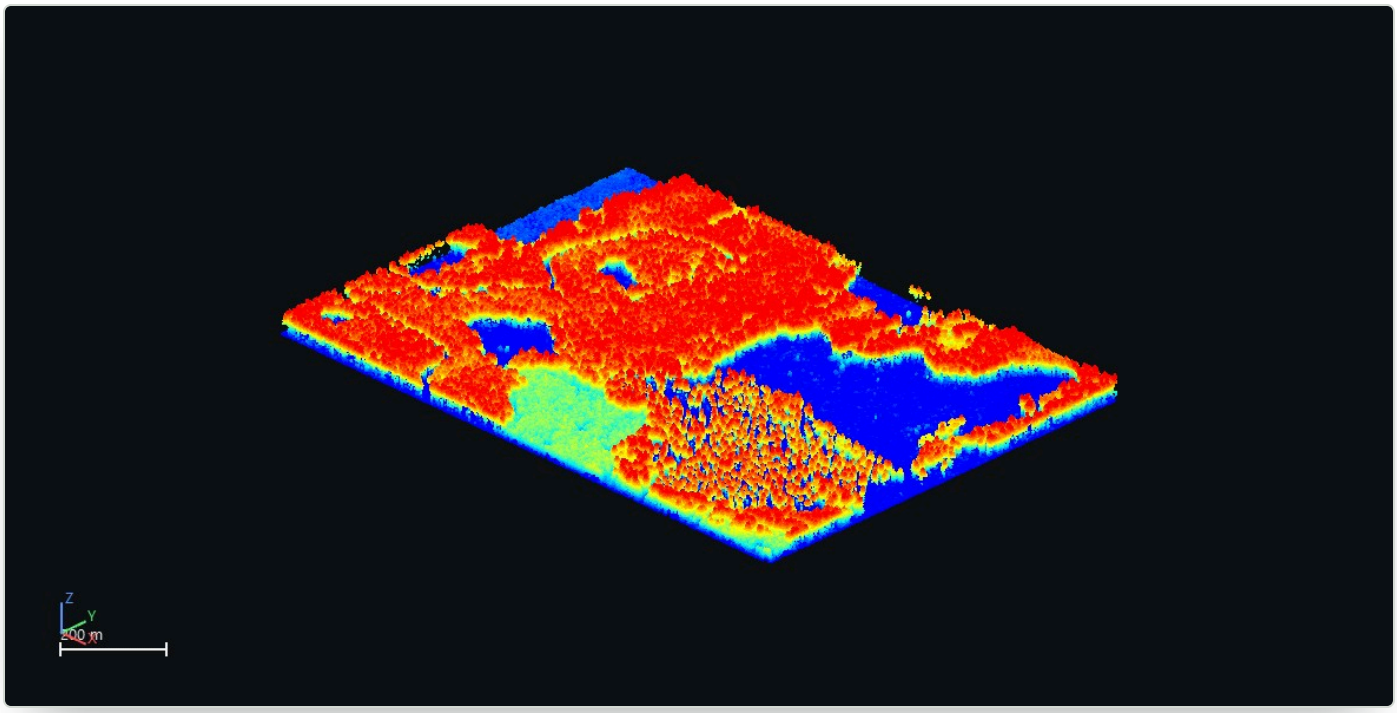
Turns each return's elevation into its height above ground (Direct TIN by default; the original elevation is kept).

Command line

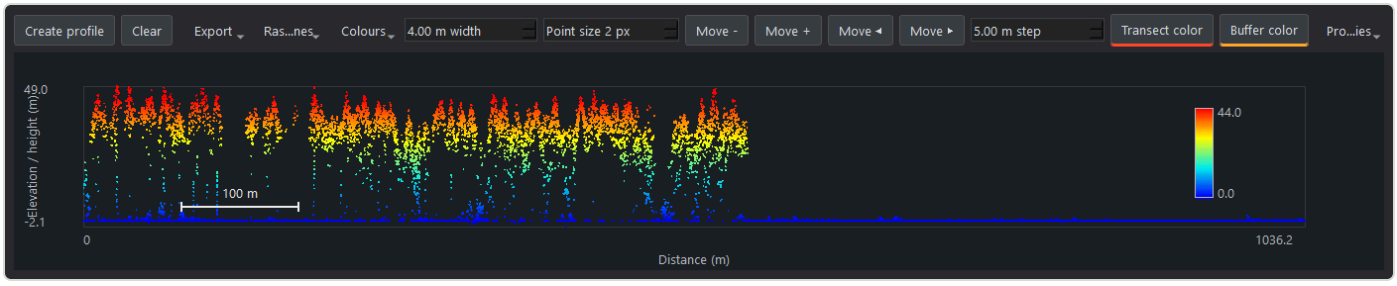
```
SilvaLiDARAirCLI.exe --tool normalize --input C:\SilvaLiDARAirExercise\03_Projects\cli_out\ground.laz --output C:\SilvaLiDARAirExercise\03_Projects\cli_out\normalized.laz --method tin
```



The window.



The normalized cloud: every return at its height above the ground, coloured by height; the ground lies flat at 0 m.



A profile of the normalized cloud: the ground is a straight line at 0 m under the crowns, whatever the relief.

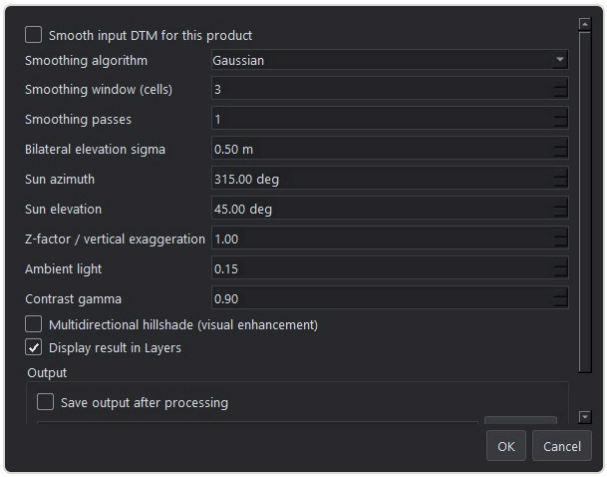
Hillshade

Tools › Terrain › Terrain Analysis › Hillshade

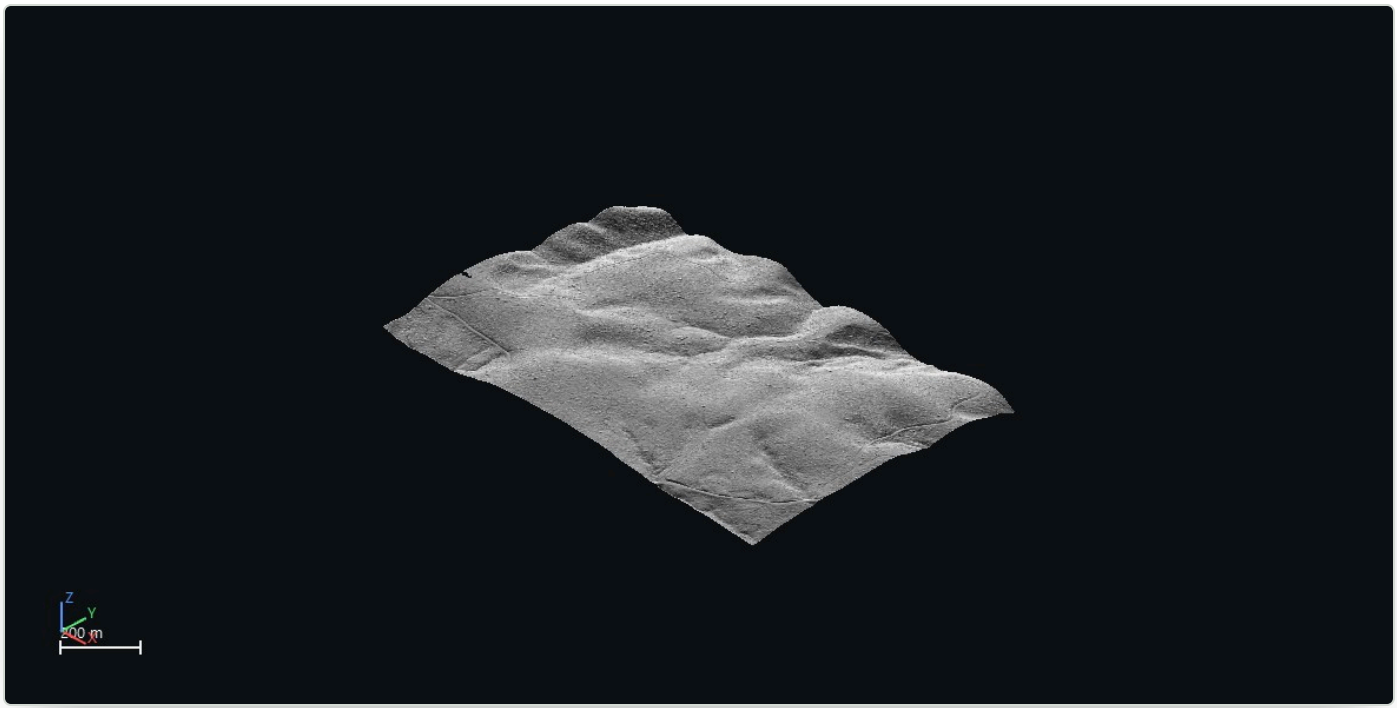
Shaded relief of the DTM.

Command line

```
SilvaLiDARAirCLI.exe --tool hillshade --input
C:\SilvaLiDARAirExercise\03_Projects\cli_out
\dtm.tif --output C:\SilvaLiDARAirExercise\03
_Projects\cli_out\hillshade.tif
```



The window.



The result on the example data.

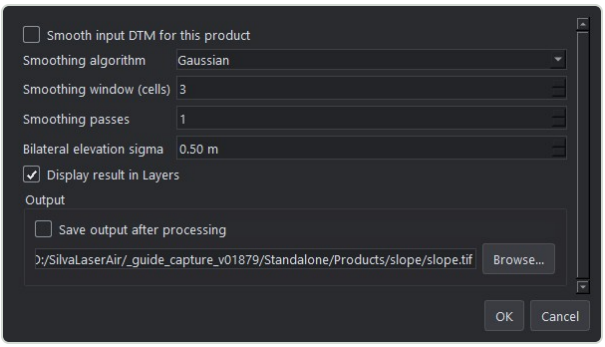
Slope

Tools › Terrain › Terrain Analysis › Slope

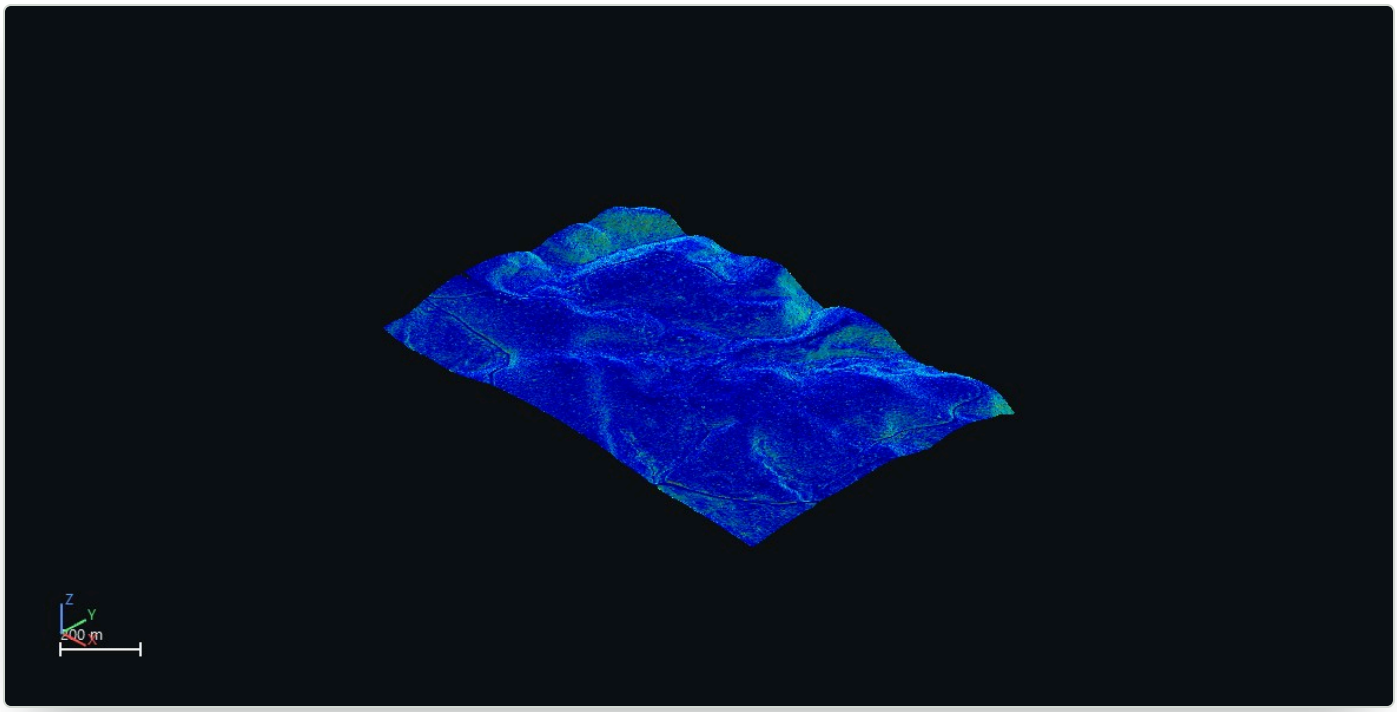
Steepness of the terrain in degrees.

Command line

```
SilvaLiDARAirCLI.exe --tool slope --input
C:\SilvaLiDARAirExercise\03_Projects\cli_out
\dtm.tif --output C:\SilvaLiDARAirExercise\03
_Projects\cli_out\slope.tif
```



The window.



The result on the example data.

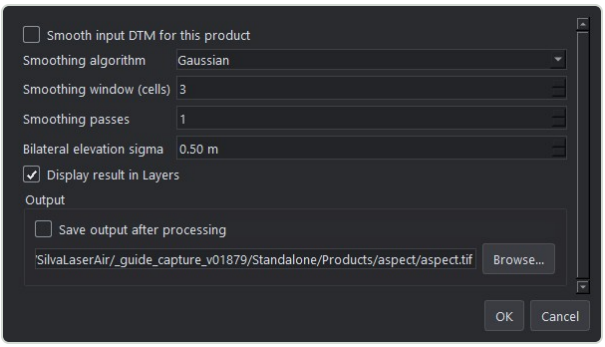
Aspect

Tools › Terrain › Terrain Analysis › Aspect

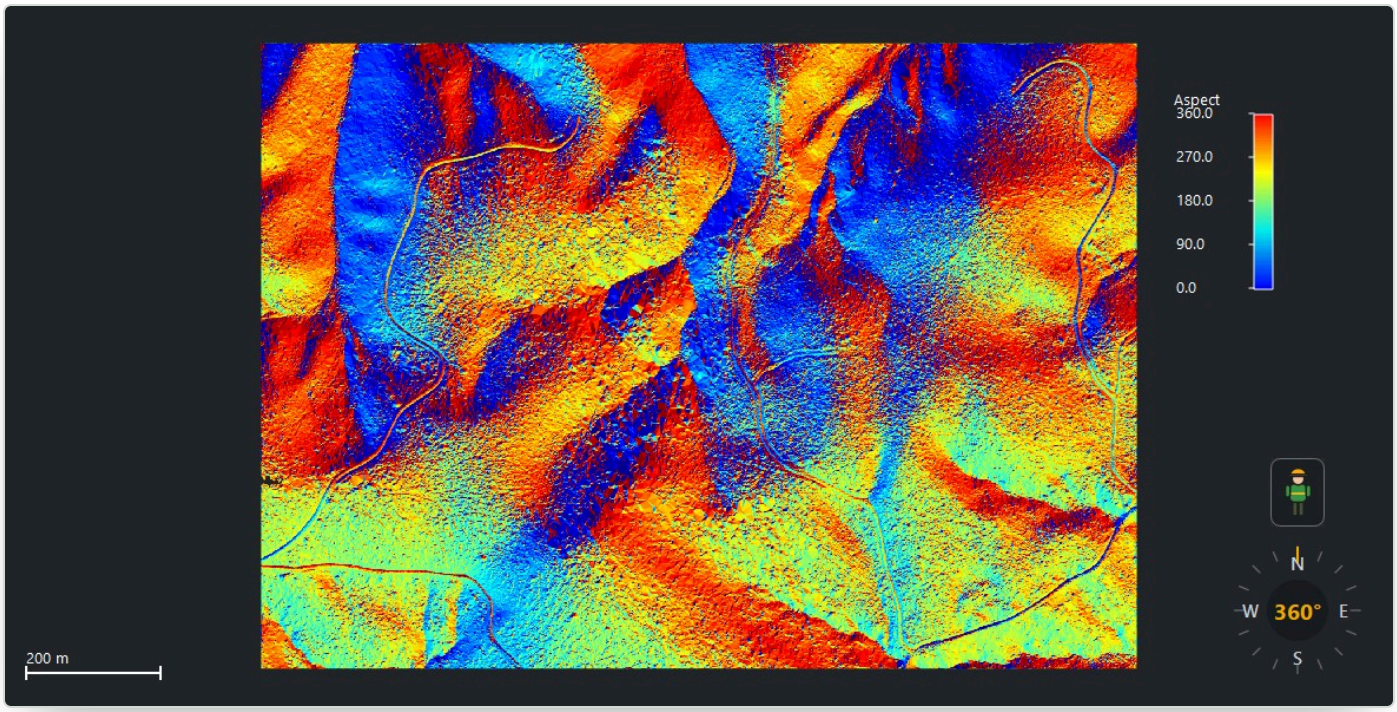
The direction each slope faces.

Command line

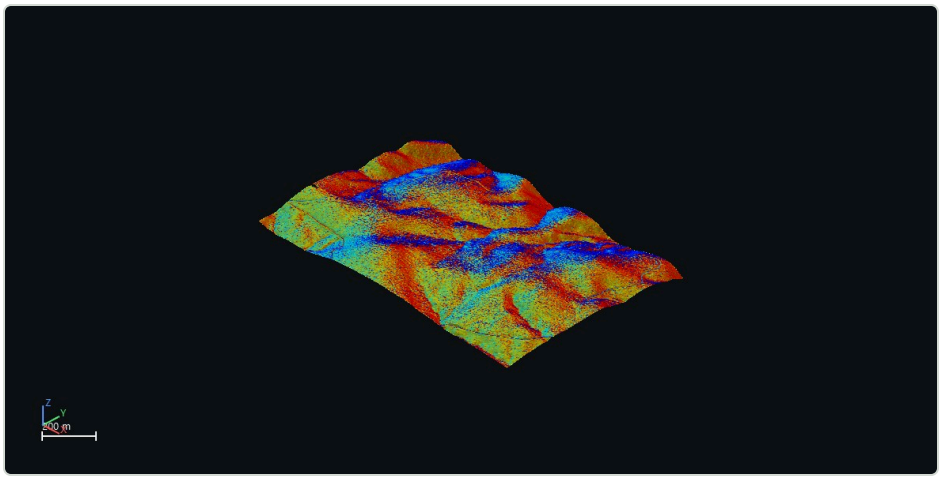
```
SilvaLiDARAirCLI.exe --tool aspect --input
C:\SilvaLiDARAirExercise\03_Projects\cli_out
\dtm.tif --output C:\SilvaLiDARAirExercise\03
_Projects\cli_out\aspect.tif
```



The window.



The result on the example data.

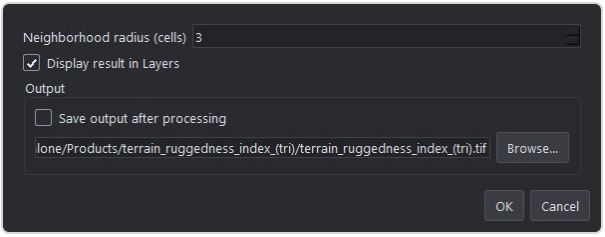


The aspect draped on the terrain in 3D.

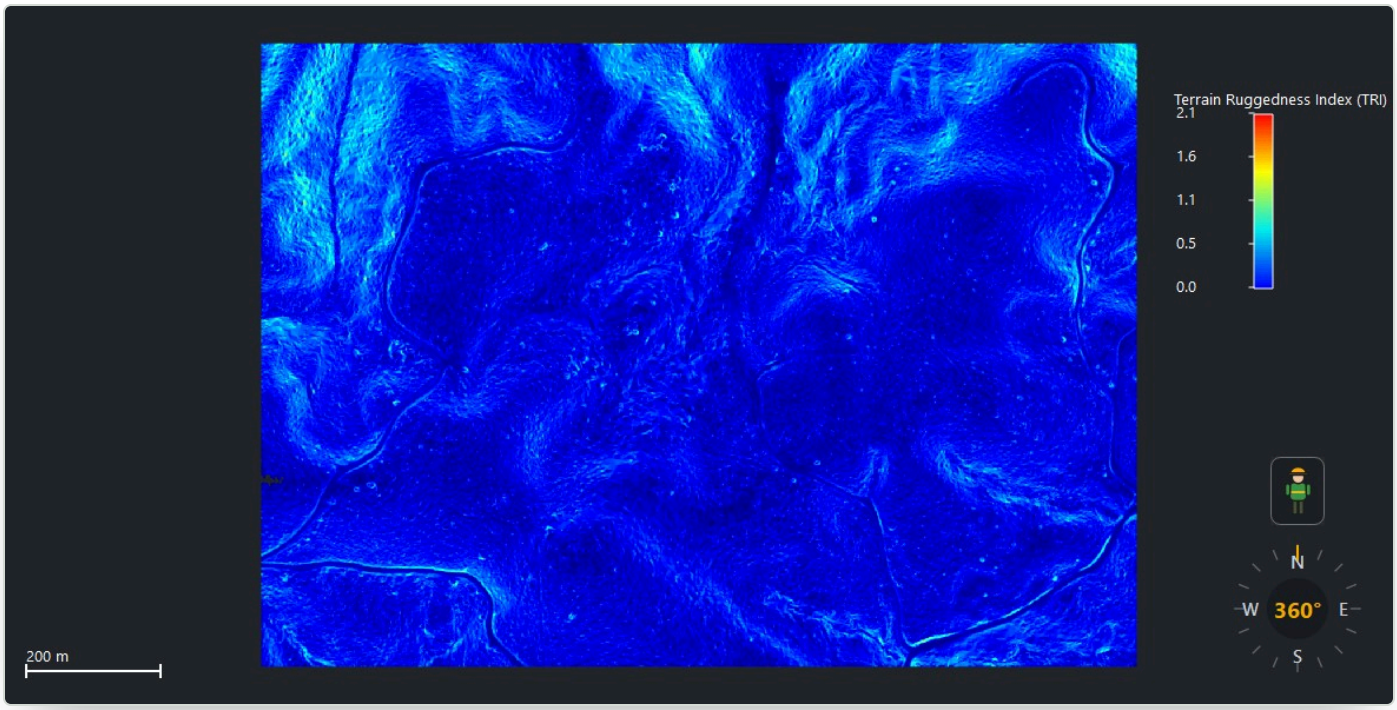
Terrain Ruggedness Index

Tools › Terrain › Terrain Analysis › TRI

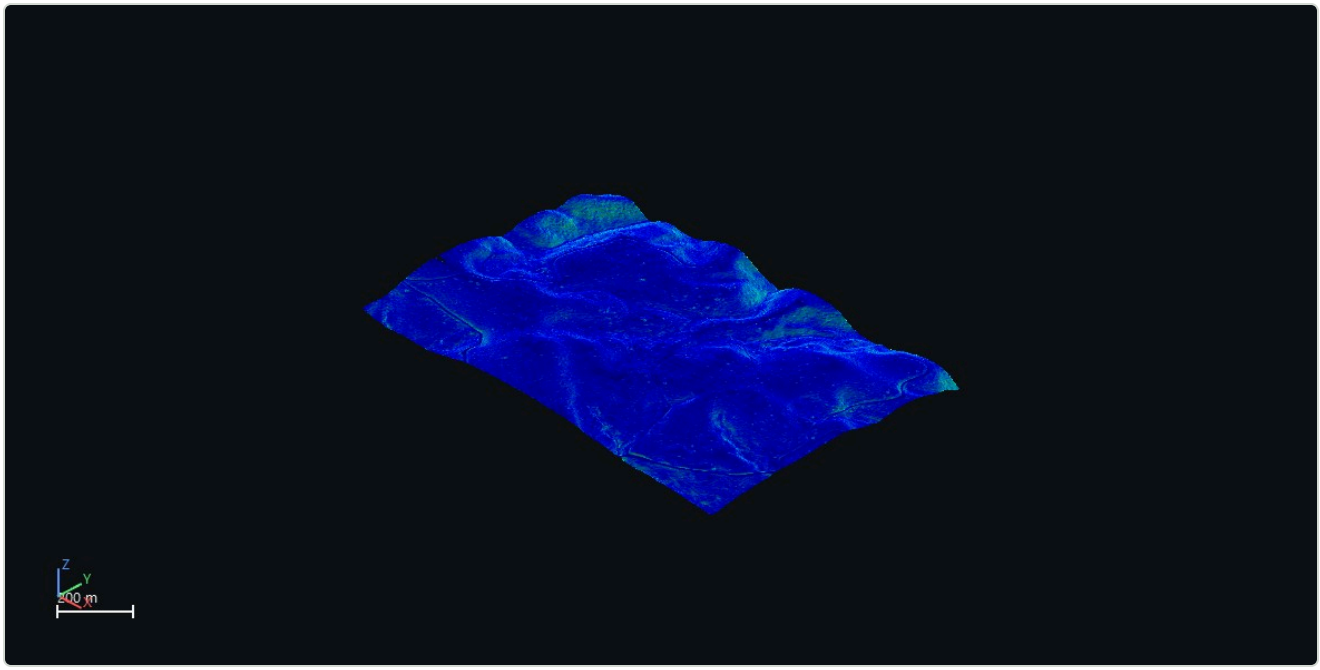
How much the elevation changes around each cell.



The window.



The result on the example data.



The terrain ruggedness index draped in 3D.

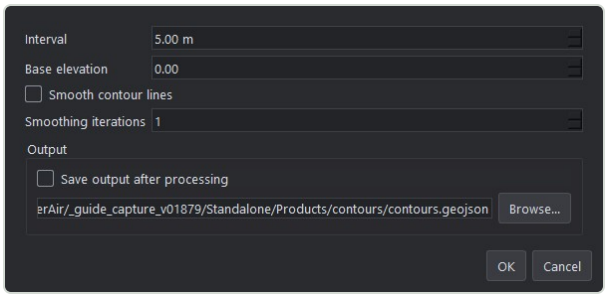
Contours

Tools › Terrain › Terrain Analysis › Contours

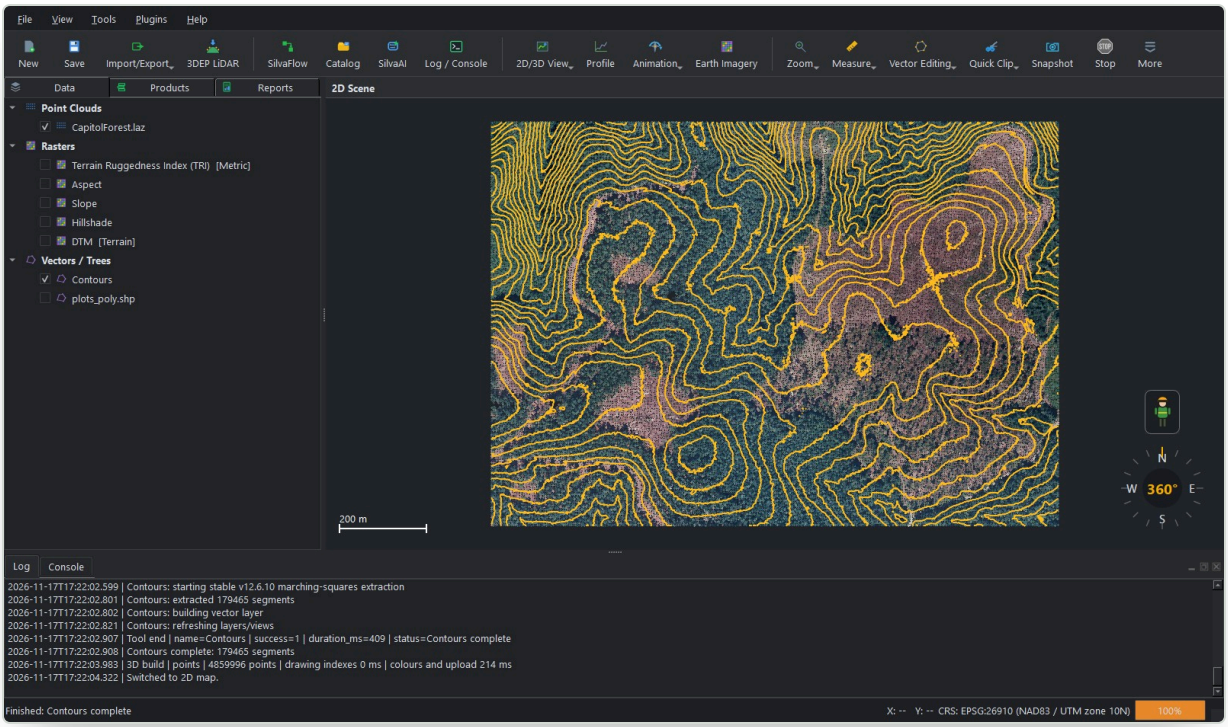
Contour lines from the DTM (5 m interval by default).

Command line

```
SilvaLiDARAirCLI.exe --tool contours --input
C:\SilvaLiDARAirExercise\03_Projects\cli_out
\dtm.tif --output C:\SilvaLiDARAirExercise\03
_Projects\cli_out\contours.geojson --interval
5
```



The window.

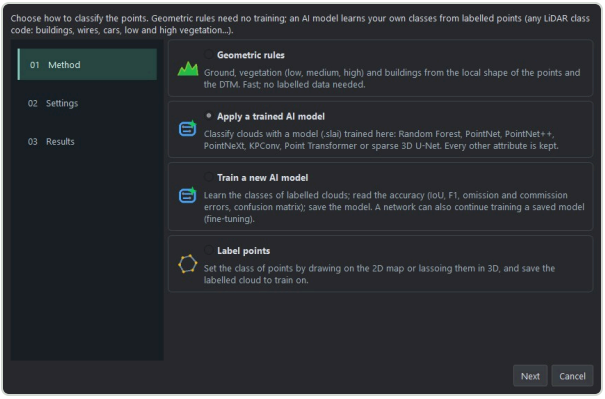


The result on the example data.

Classification

Tools › Canopy › Classification

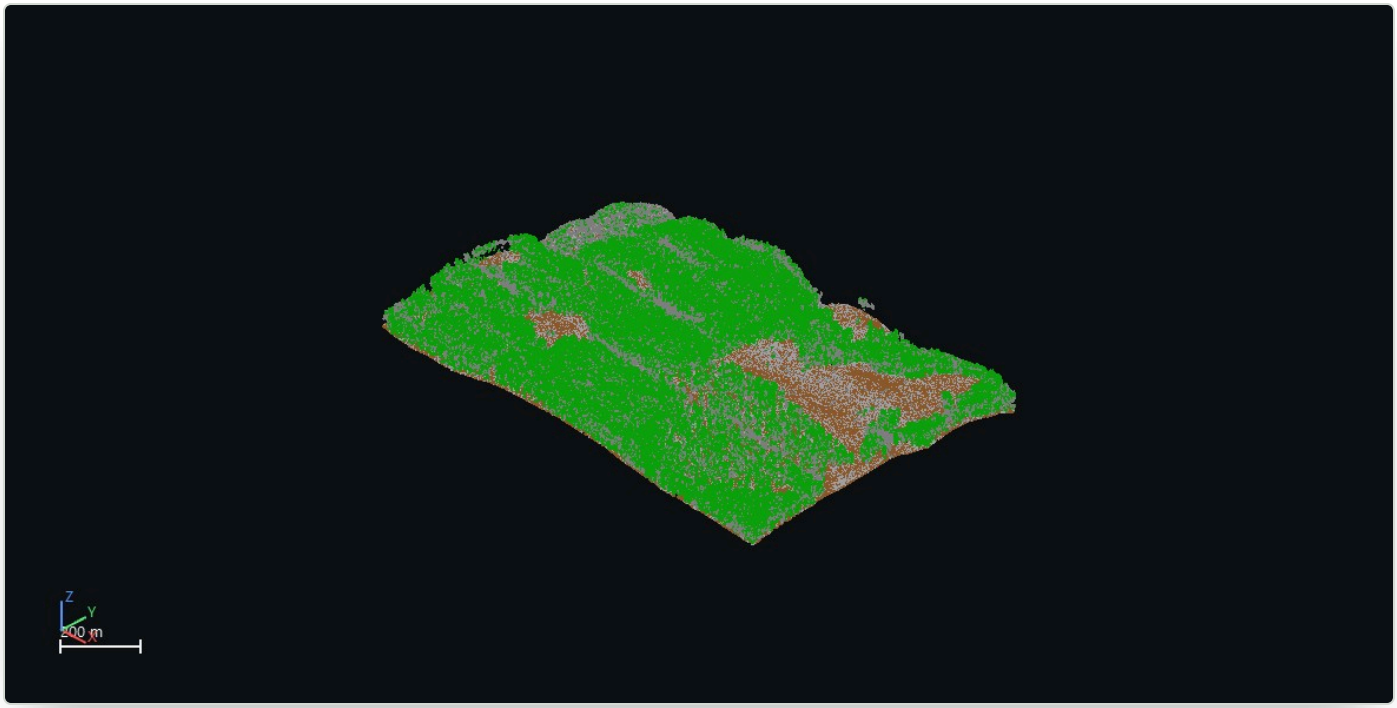
One panel for every way of classifying points: geometric rules (ground, low/medium/high vegetation, buildings from local shape and the DTM), applying a trained AI model, training a new one (Random Forest, PointNet, PointNet++ or PointNeXt, with fine-tuning), and labelling points to train on. Exercise 16 walks through the AI methods.



The window.

Command line

```
SilvaLiDARAirCLI.exe --tool vegetation-classify --input C:\SilvaLiDARAirExercise\03_Projects\cli_out\ground.laz --output C:\SilvaLiDARAirExercise\03_Projects\cli_out\classified.laz
```

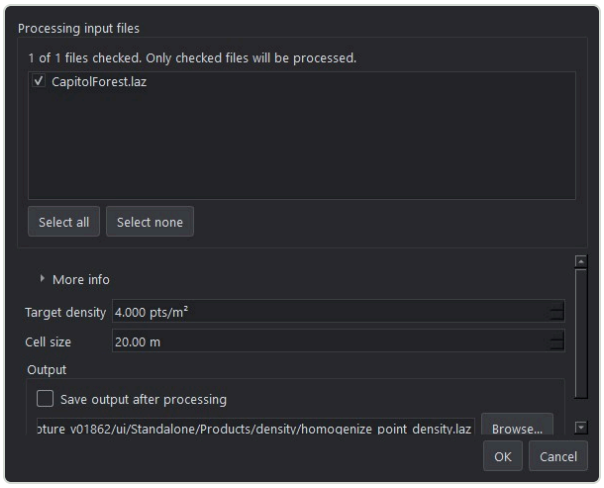


The result on the example data.

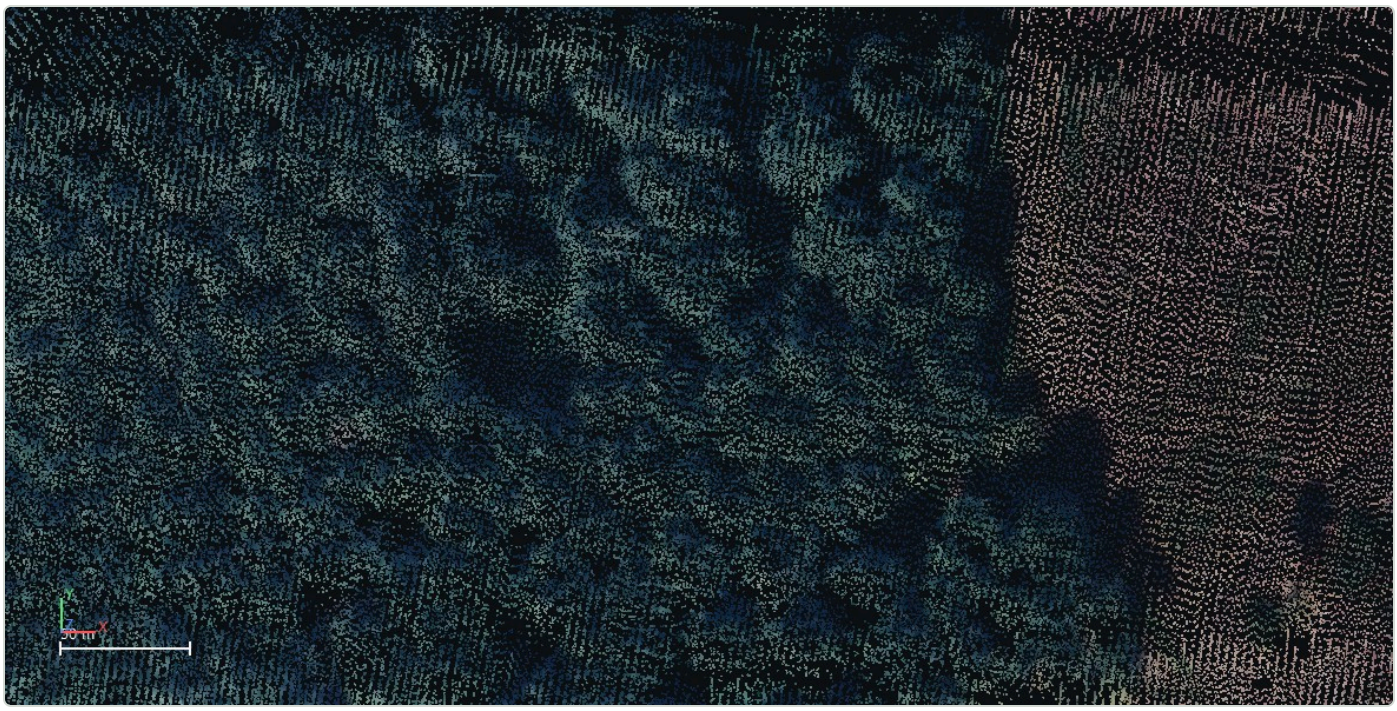
Homogenize Point Density

Tools › Point Cloud › Homogenize Point Density

Caps the points per cell so overlapping flight lines do not inflate metrics.



The window.



Before Homogenize Point Density, seen from above: 4,859,996 points.

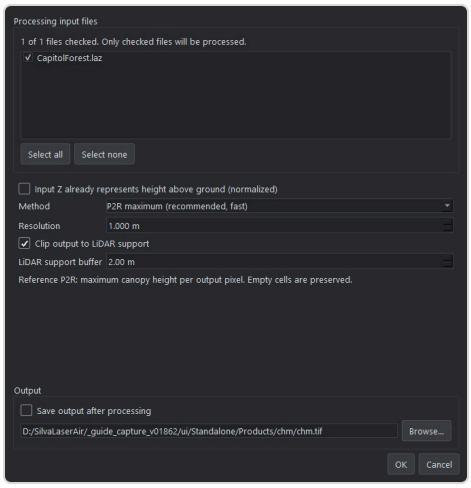
CHM

Tools › Canopy › CHM

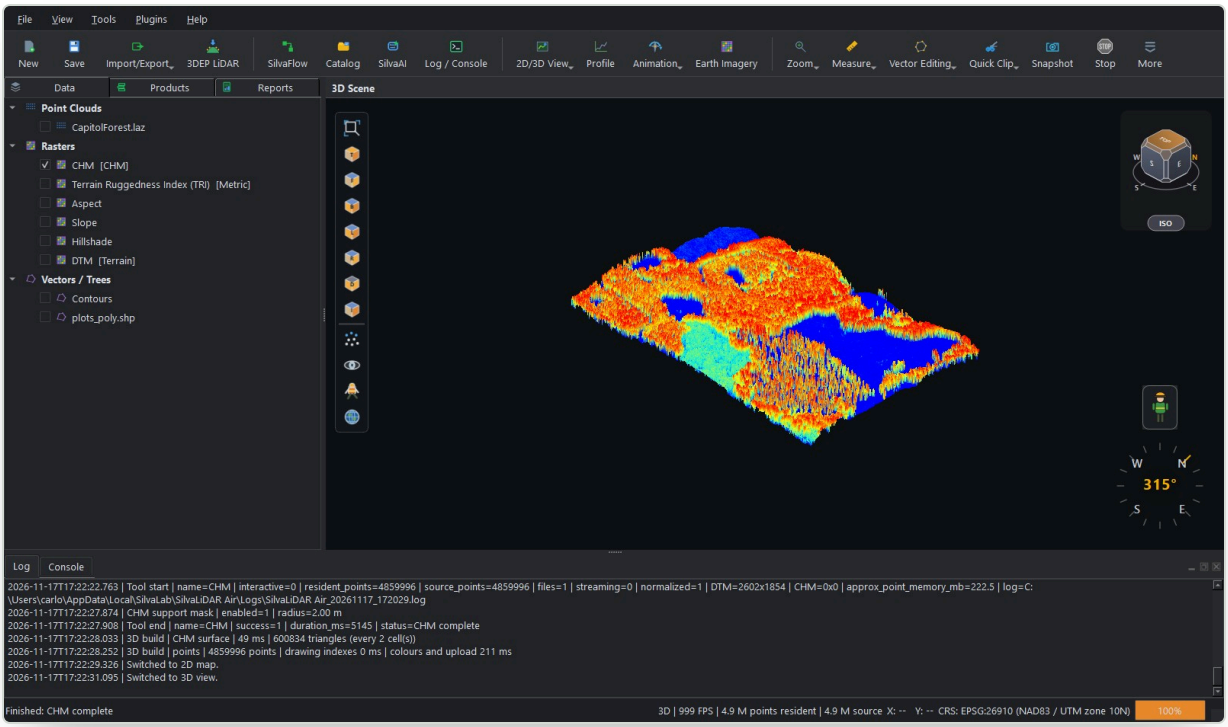
Canopy height model: P2R maximum by default; P2R with subcircle, pit-free, spike-free, TIN, IDW and more.

Command line

```
SilvaLiDARAirCLI.exe --tool chm --input C:\SilvaLiDARAirExercise\03_Projects\cli_out\normalized.laz --output C:\SilvaLiDARAirExercise\03_Projects\cli_out\chm.tif --method pitfree --resolution 0.5
```



The window.



The result on the example data.

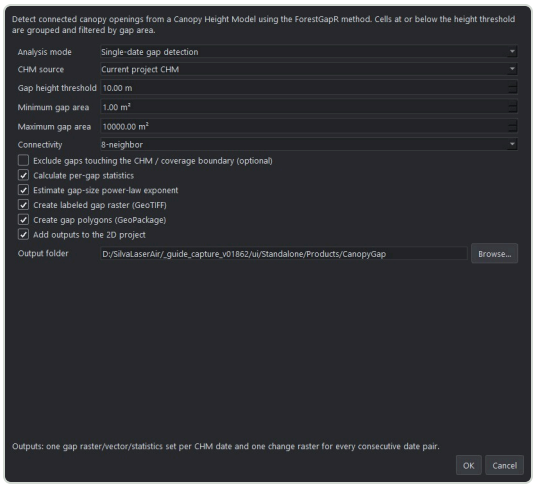
Canopy Gap

Tools › Canopy › Canopy Gap

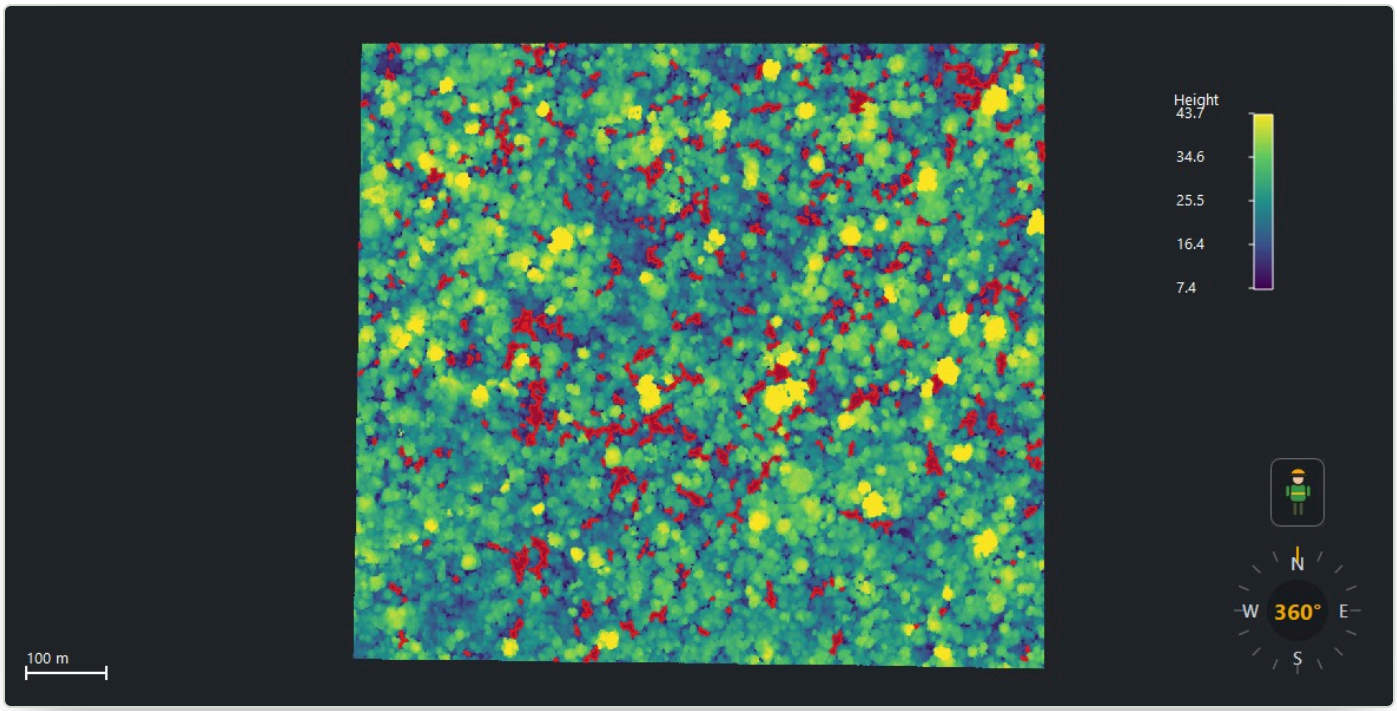
Openings in the canopy below a height (10 m), from 1 to 10,000 m², with per-gap statistics.

Command line

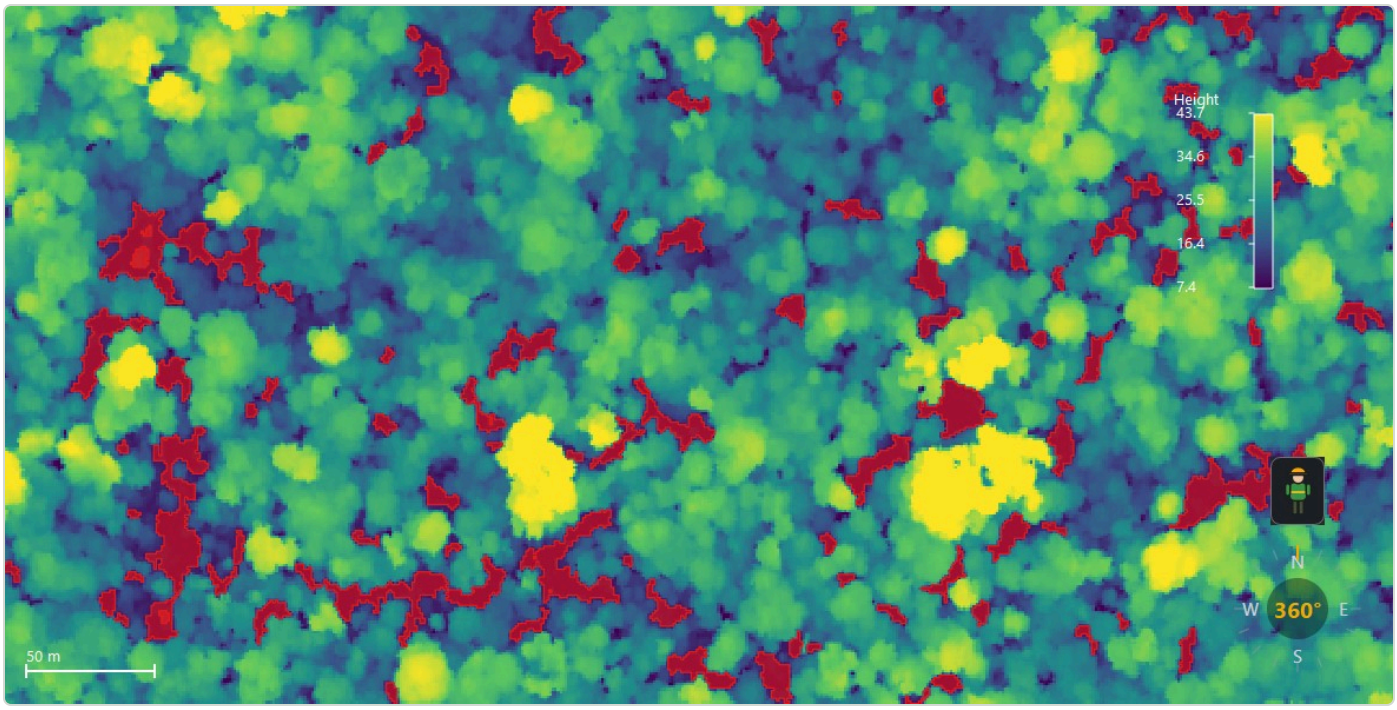
```
SilvaLiDARAirCLI.exe --tool canopy-gap --input C:\SilvaLiDARAirExercise\03_Projects\cli_out\chm.tif --output C:\SilvaLiDARAirExercise\03_Projects\cli_out\gaps --threshold 10 --min-area 25
```



The window.



Canopy Gap on tropical forest (Fazenda Cauaxi, Pará, Brazil, in the exercise data): the gaps (red) over the CHM (viridis palette), openings below 10 m from 10 m² up.



Closer: each gap follows the edge of the crowns around it; logging roads and skid trails open long gaps.

Note The **Minimum gap area** was set to 10 m^2 for these pictures. With the default of 1 m^2, the one-cell holes between neighbouring crowns are counted as gaps too.

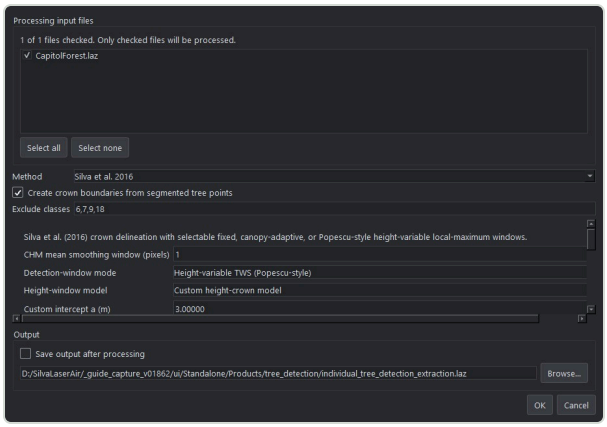
Individual Tree Detection & Extraction

Tools › Canopy › Individual Tree Detection & Extraction

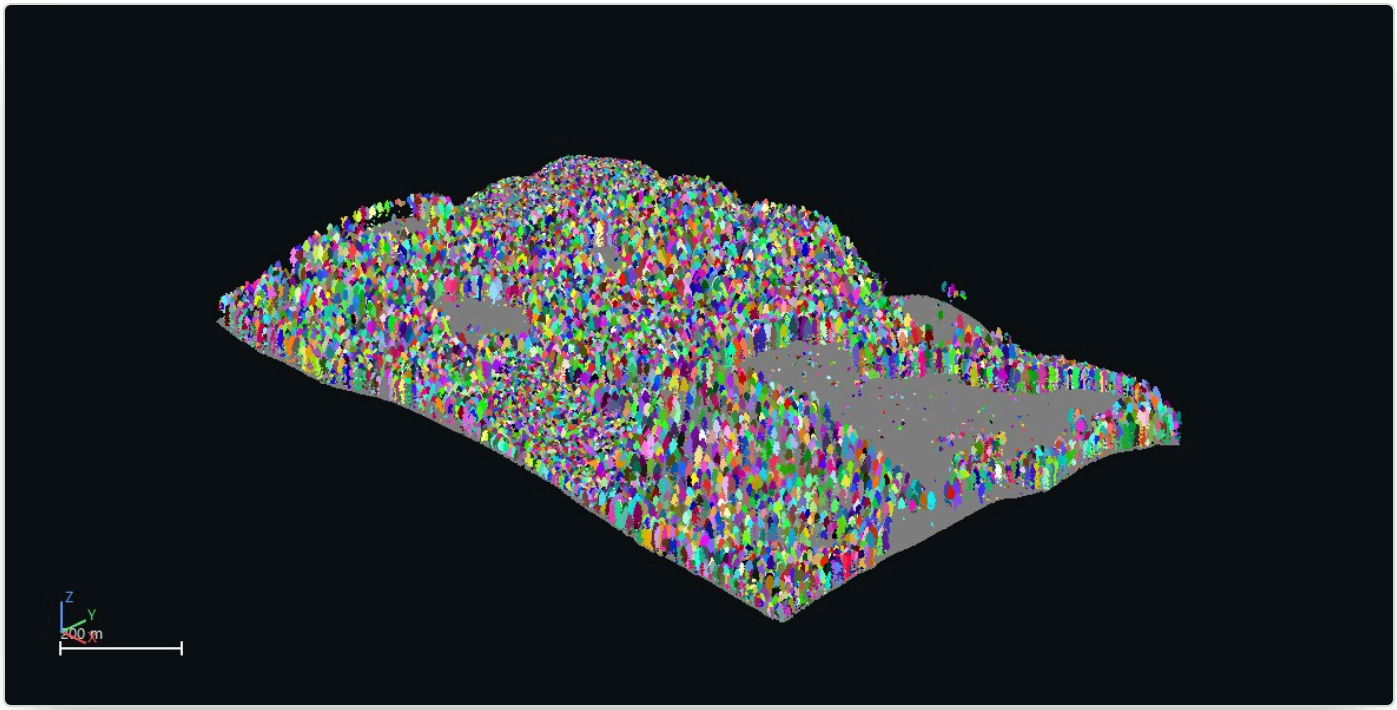
Finds each tree (Silva 2016 by default; Li 2012, Dalponte 2016, watershed, AMS3D and more): tree IDs, tops and crowns.

Command line

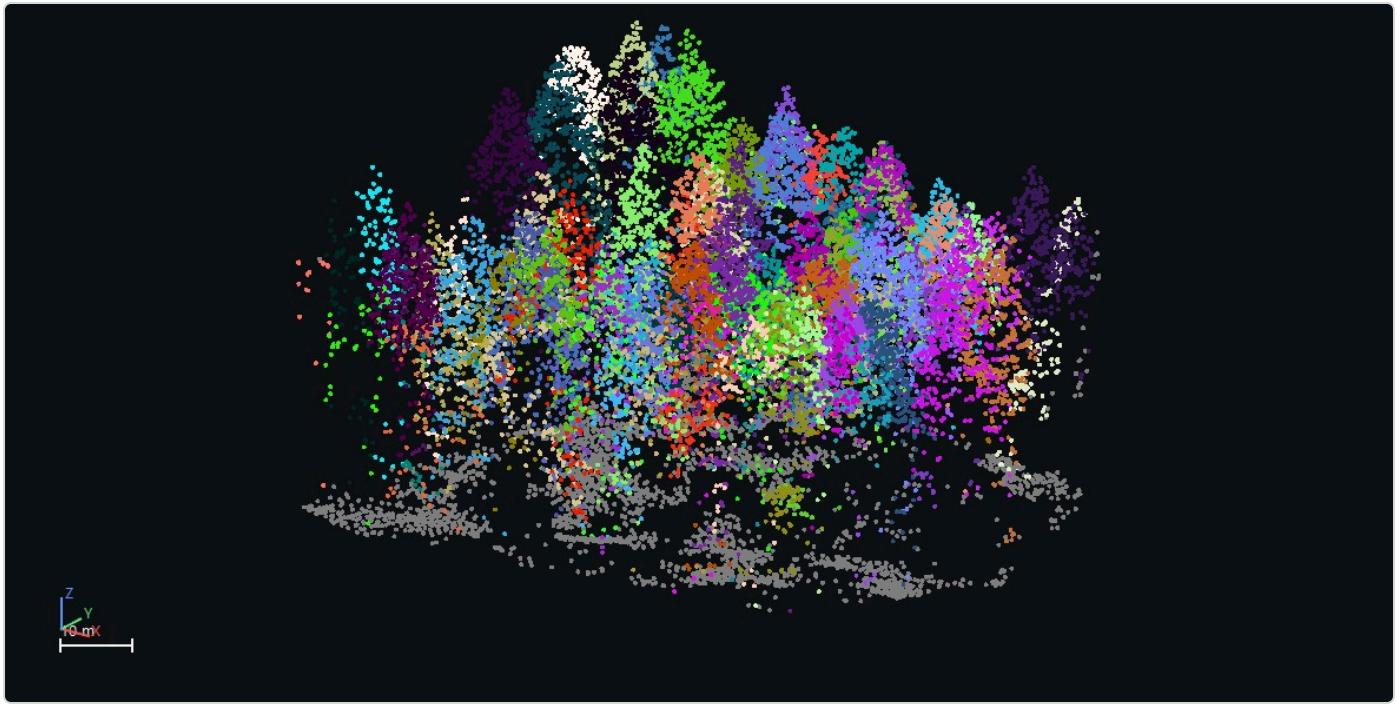
```
SilvaLiDARAirCLI.exe --tool trees --method silva2016 --input C:\SilvaLiDARAirExercise\03_Projects\cli_out\normalized.laz --output C:\SilvaLiDARAirExercise\03_Projects\cli_out\trees.laz --metrics-csv C:\SilvaLiDARAirExercise\03_Projects\cli_out\trees.csv
```



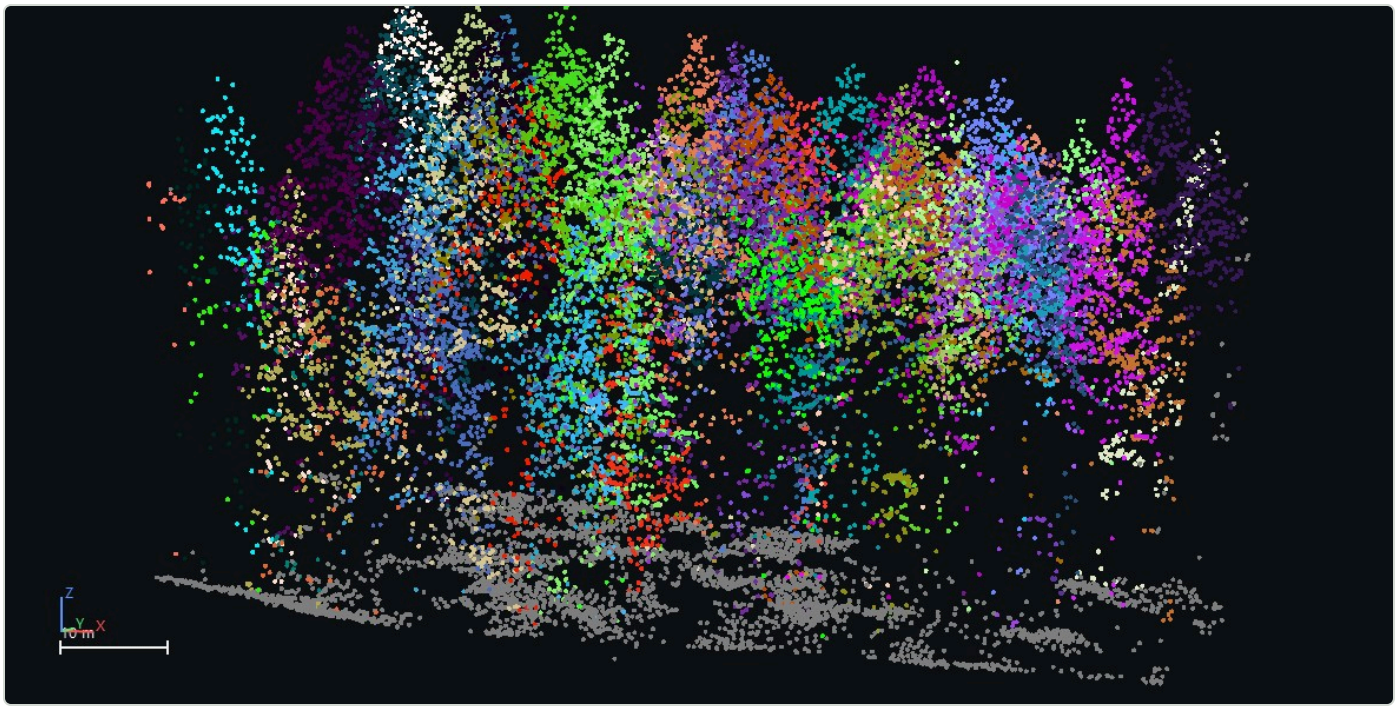
The window.



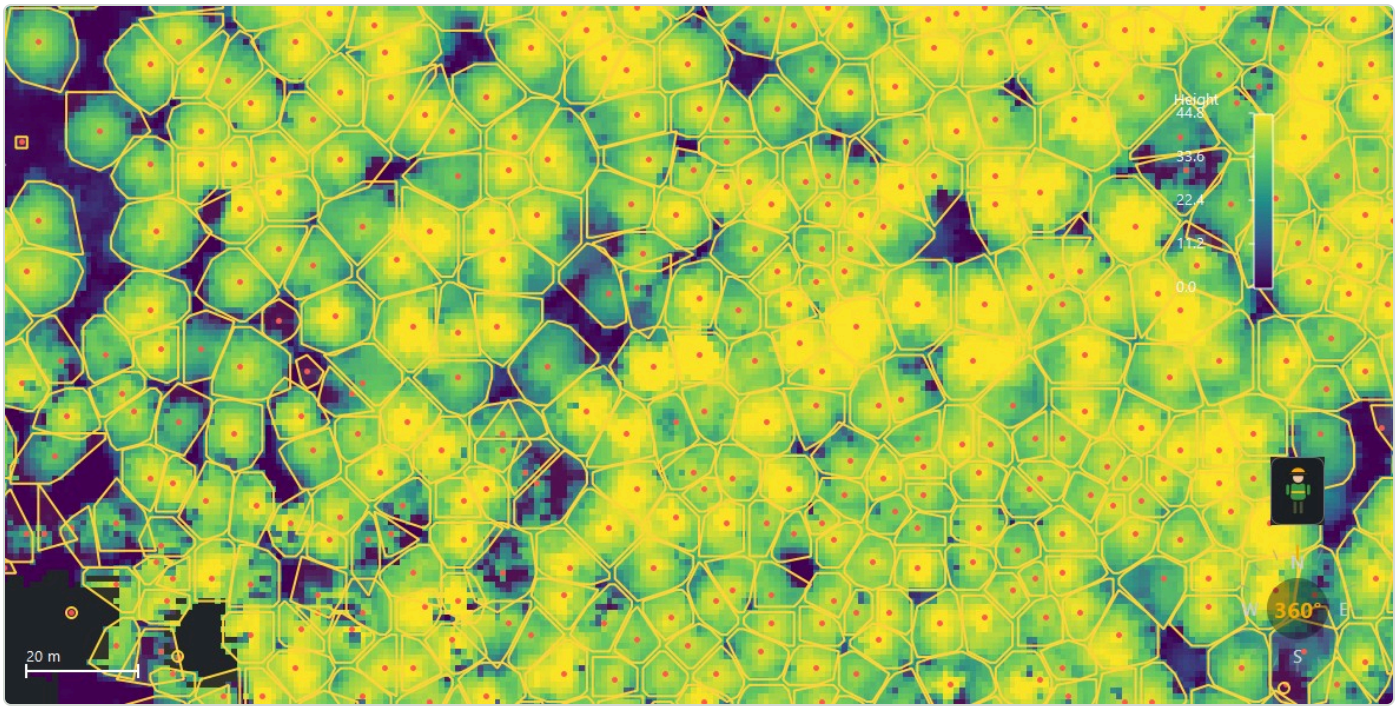
The whole stand: every detected tree in its own colour.



Closer: an 80 m square of the stand, each tree in its own colour from its top down to the ground (grey: ground).



From the side: neighbouring crowns are split where they meet, and each stem keeps the colour of its crown.



Crown Boundaries and Tree Tops over the CHM (viridis palette): one outline and one top per detected tree.

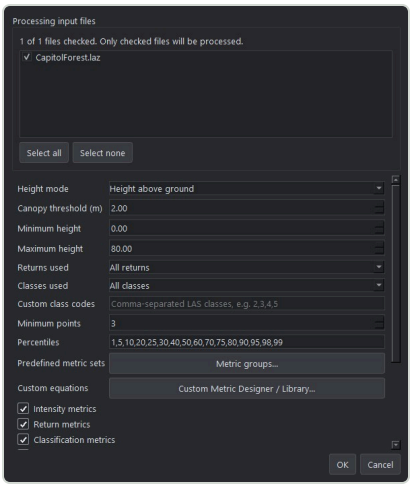
Cloud Metrics

Tools › Metrics › Cloud Metrics

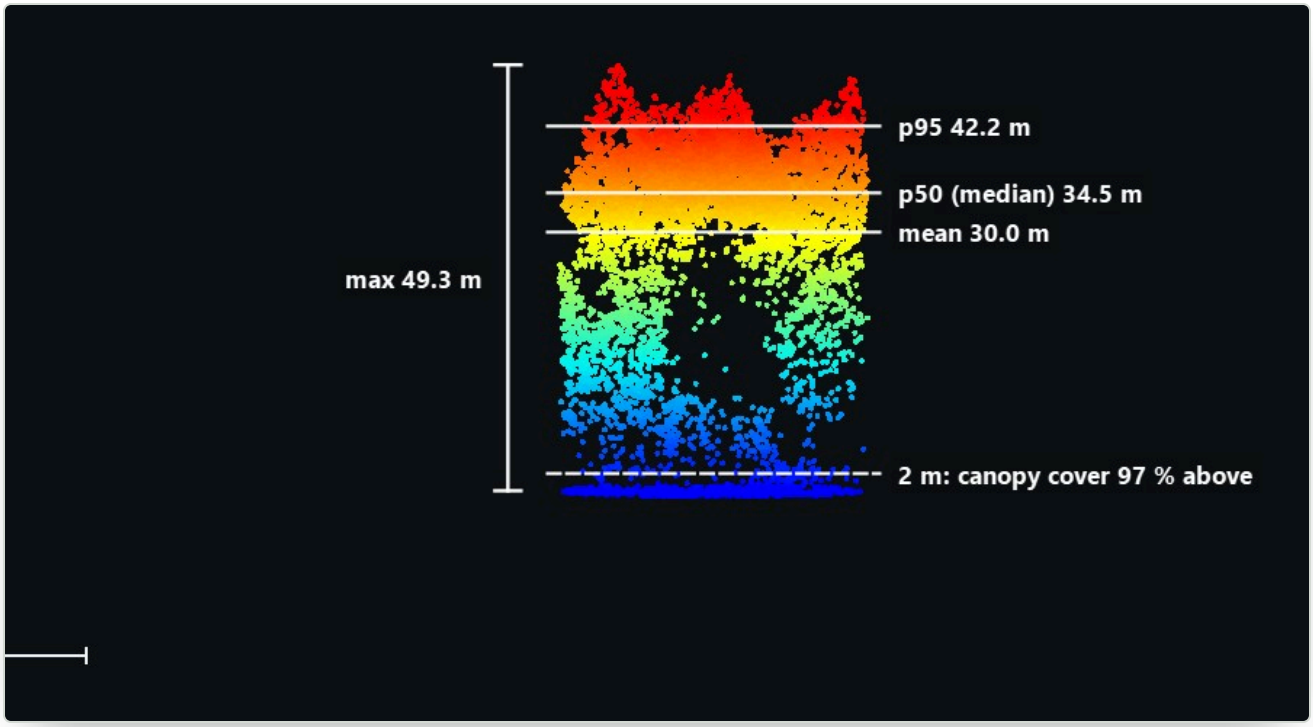
Height, density and cover metrics of the point clouds you pass: the whole stand, one clip, or several files (plot clips, tiles) with one row per file or all together. Your own metrics come from the **Custom Metric Designer** (Exercise 8). From the command line, `cloud-metrics` does the same per file, or per polygon with `--shape`.

Command line

```
SilvaLiDARAirCLI.exe --tool cloud-metrics --input-dir C:\SilvaLiDARAirExercise\01_Sites\01_CapitolStateForestWA\01_LAZ --shape C:\SilvaLiDARAirExercise\01_Sites\01_CapitolStateForestWA\02_SHP\plots_poly.shp --id-field Id --output-dir C:\SilvaLiDARAirExercise\03_Projects\cli_out\plot_metrics --custom-metrics "z_range=max(Z)-min(Z);p95_minus_p50=p95-p50;dens_first_above_10m=100*sum((ReturnNumber==1)*(HAG>10))/sum(ReturnNumber==1)"
```



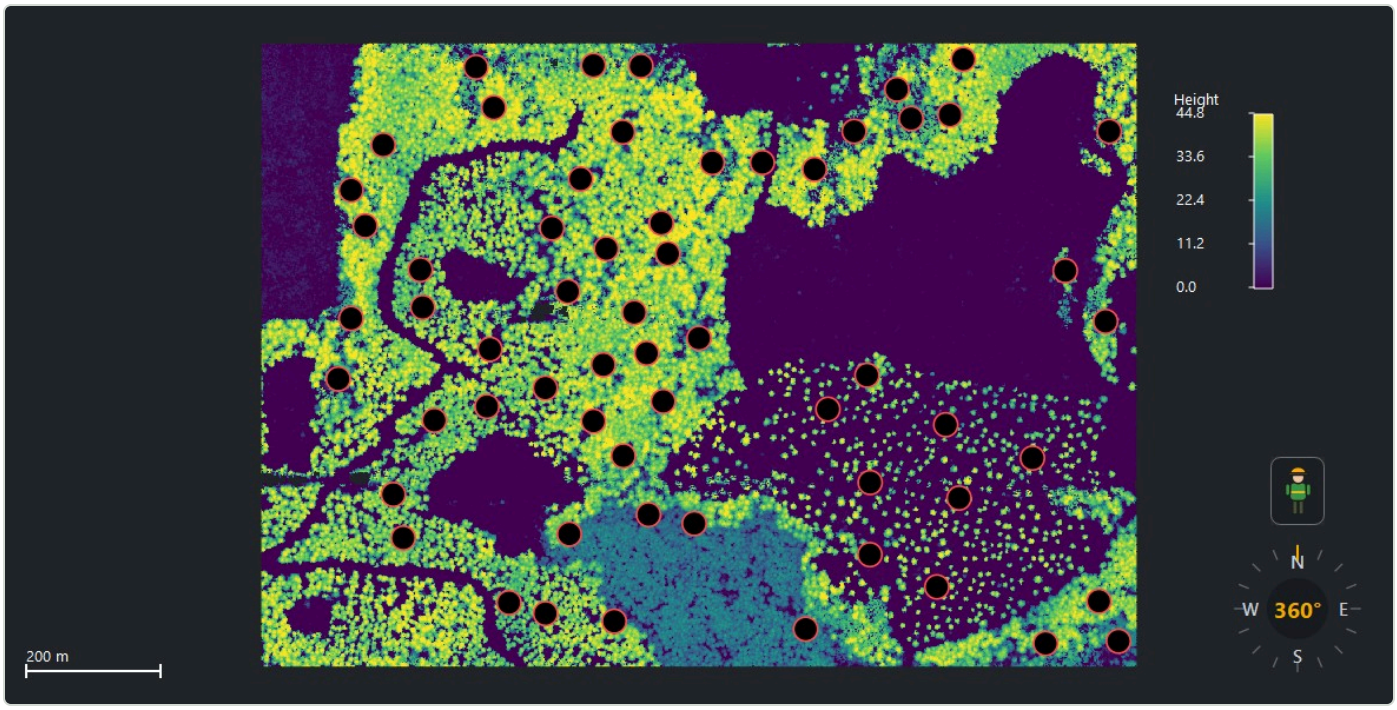
The window.



Plot 22 from the side, heights above ground, with the Cloud Metrics of its returns: maximum height, 95th percentile, median, mean, and the 2 m threshold of canopy cover.

The first rows of the Cloud Metrics table for the 60 plots (one row per plot; the file has about 150 metrics).

plot	returns	zmax	zmean	zq95	zsd	cover %	% > 30 m
0	5906	54.99	33.03	47.16	14.03	93.15	74.11
1	6888	43.56	28.33	38.32	9.23	98.54	54.02
2	3863	48.71	23.13	41.58	15.45	70.11	46.44
3	4980	49.64	31.11	42.27	9.8	96.98	67.75
4	2351	48.06	25.77	41.91	14.57	82.35	53.89
5	6619	53	29.31	45.41	14.72	91.82	66.07



The 60 plots (dark circles) over the CHM: Cloud Metrics gives one row of metrics for each plot clipped from the stand.

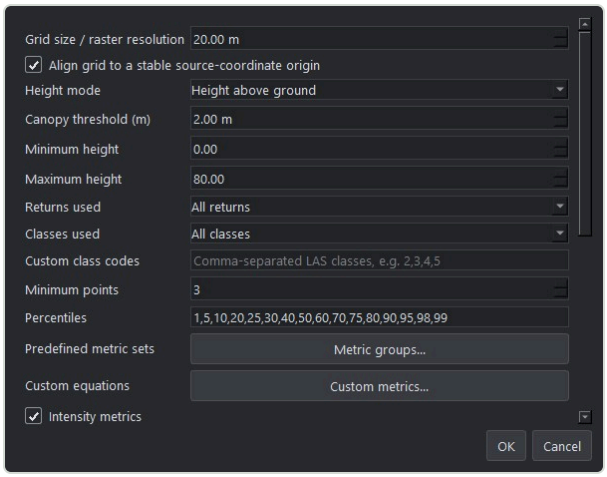
Grid Metrics

Tools › Metrics › Grid Metrics

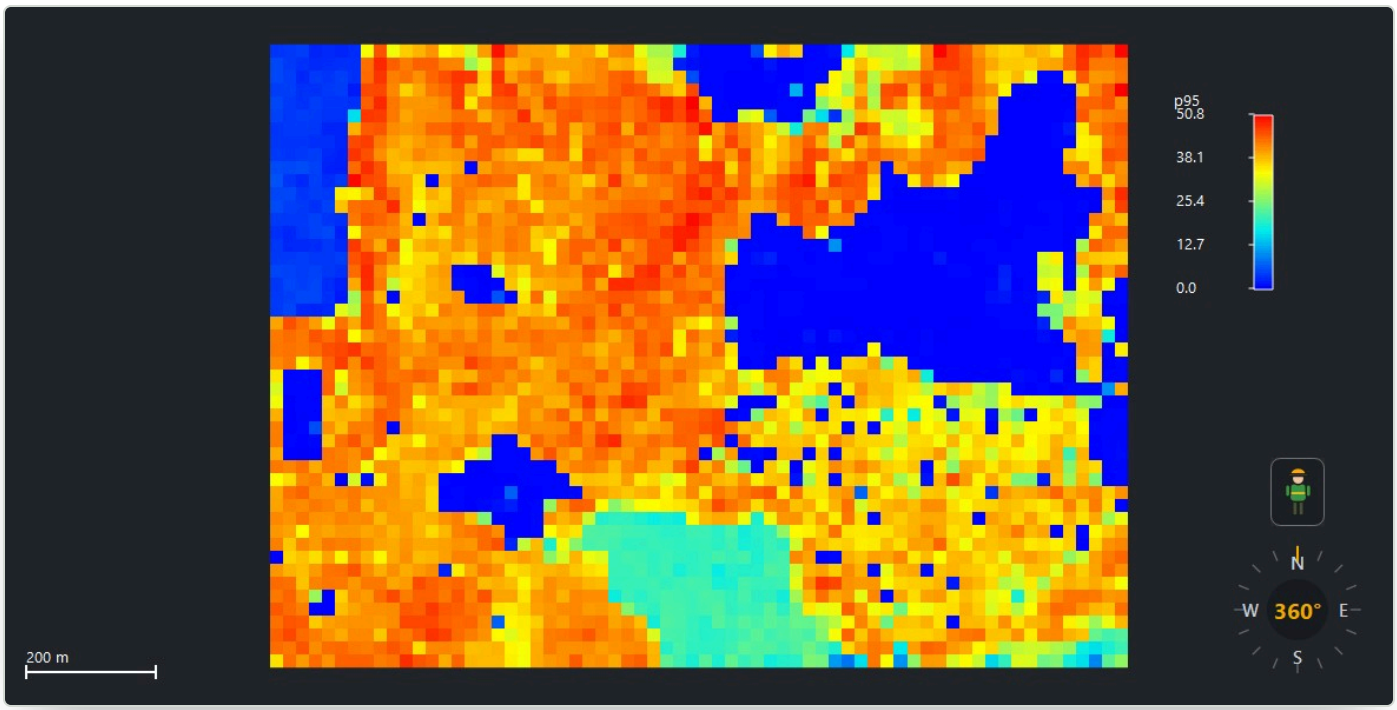
The same metrics for every cell of a grid (20 m by default), with your custom metrics, as a CSV and one GeoTIFF per metric.

Command line

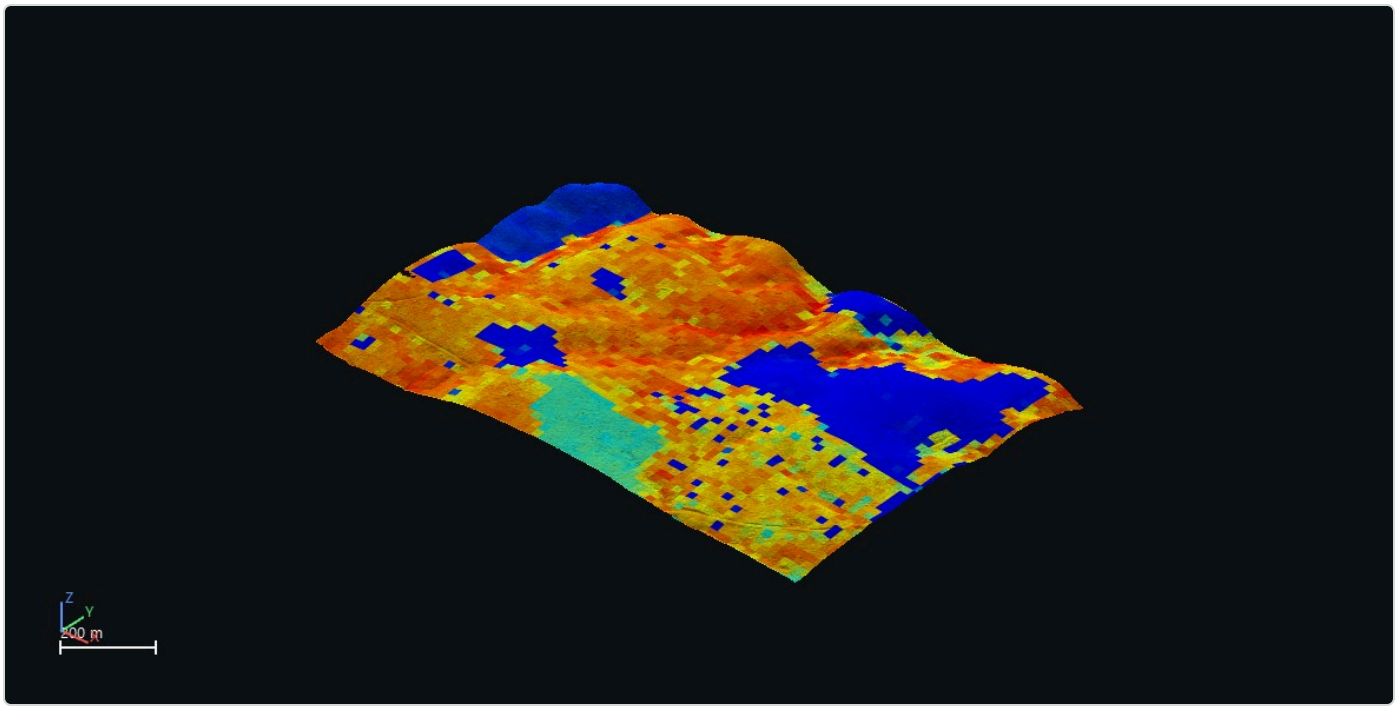
```
SilvaLiDARAirCLI.exe --tool grid-metrics --input-dir C:\SilvaLiDARAirExercise\01_Sites\01_CapitolStateForestWA\01_LAZ --output-dir C:\SilvaLiDARAirExercise\03_Projects\cli_out\grid --grid-resolution 20 --grid-rasters 1 --custom-metrics "z_range=max(Z)-min(Z);p95_minus_p50=p95-p50;dens_first_above_10m=100*sum((ReturnNumber==1)*(HAG>10))/sum(ReturnNumber==1)"
```



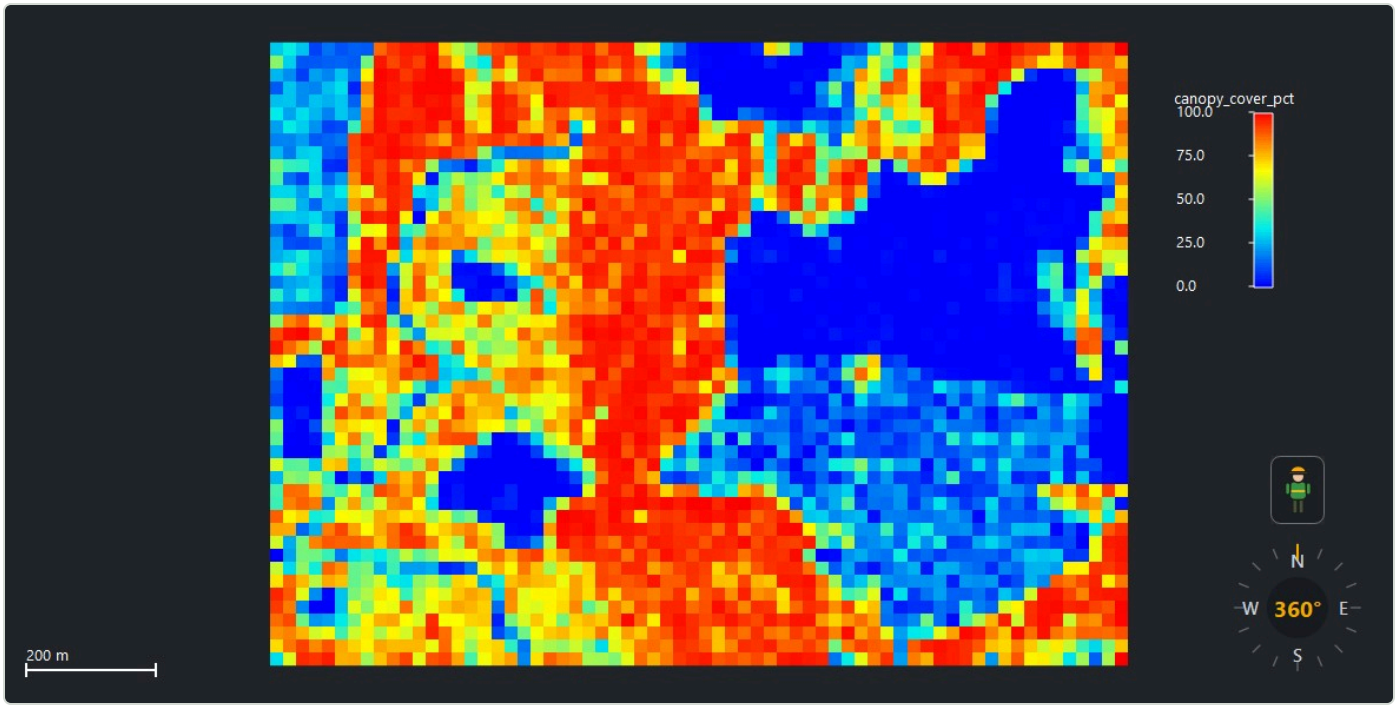
The window.



The 95th percentile of height (p95) in every 20 m cell, with its legend.



The same height raster draped on the DTM in 3D: tall stands high, harvest units low.



Another Grid Metrics raster: canopy cover (% of first returns above 2 m) in every 20 m cell.

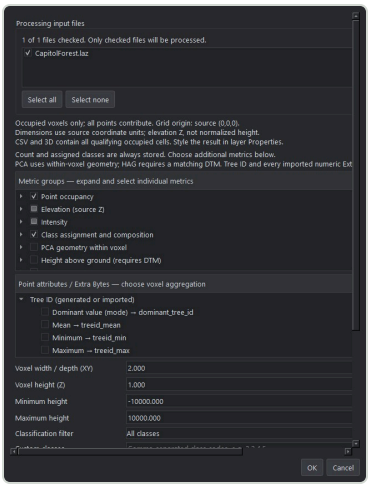
Voxel Metrics

Tools › Metrics › Voxel Metrics

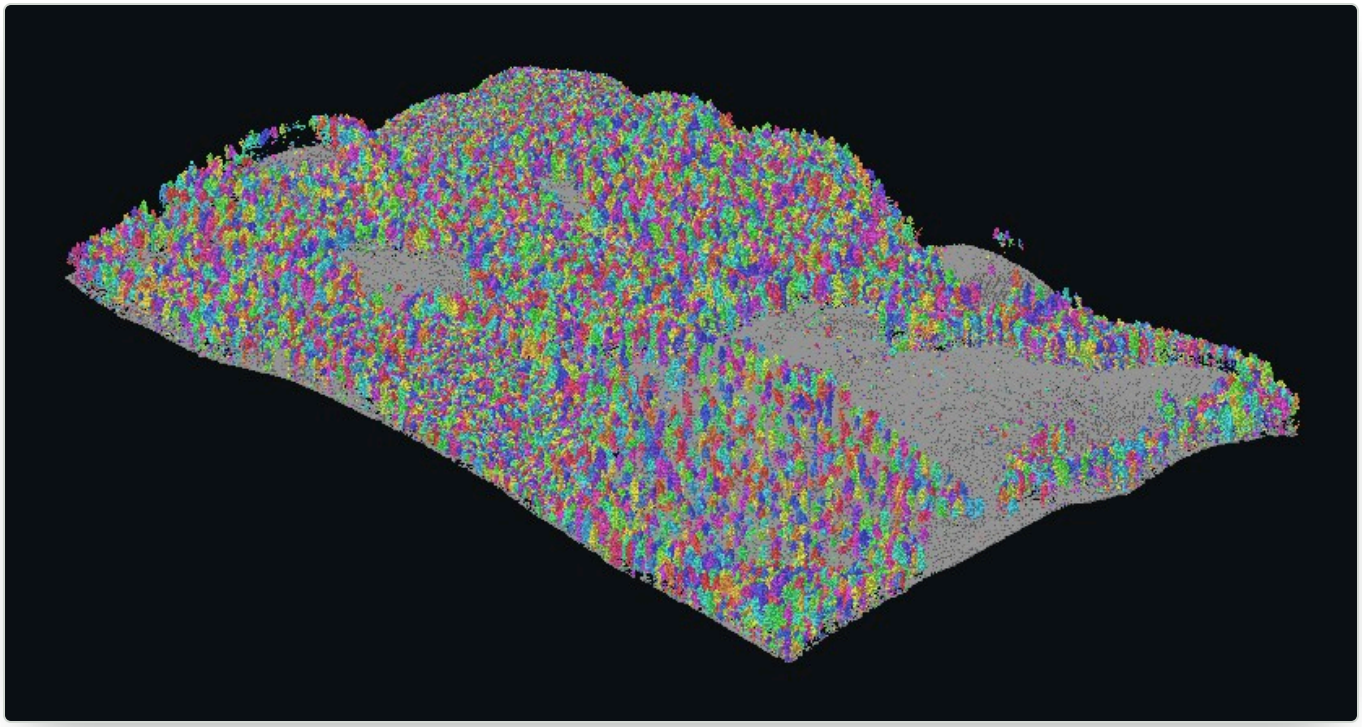
Metrics in 3D cells (2 m × 1 m by default).

Command line

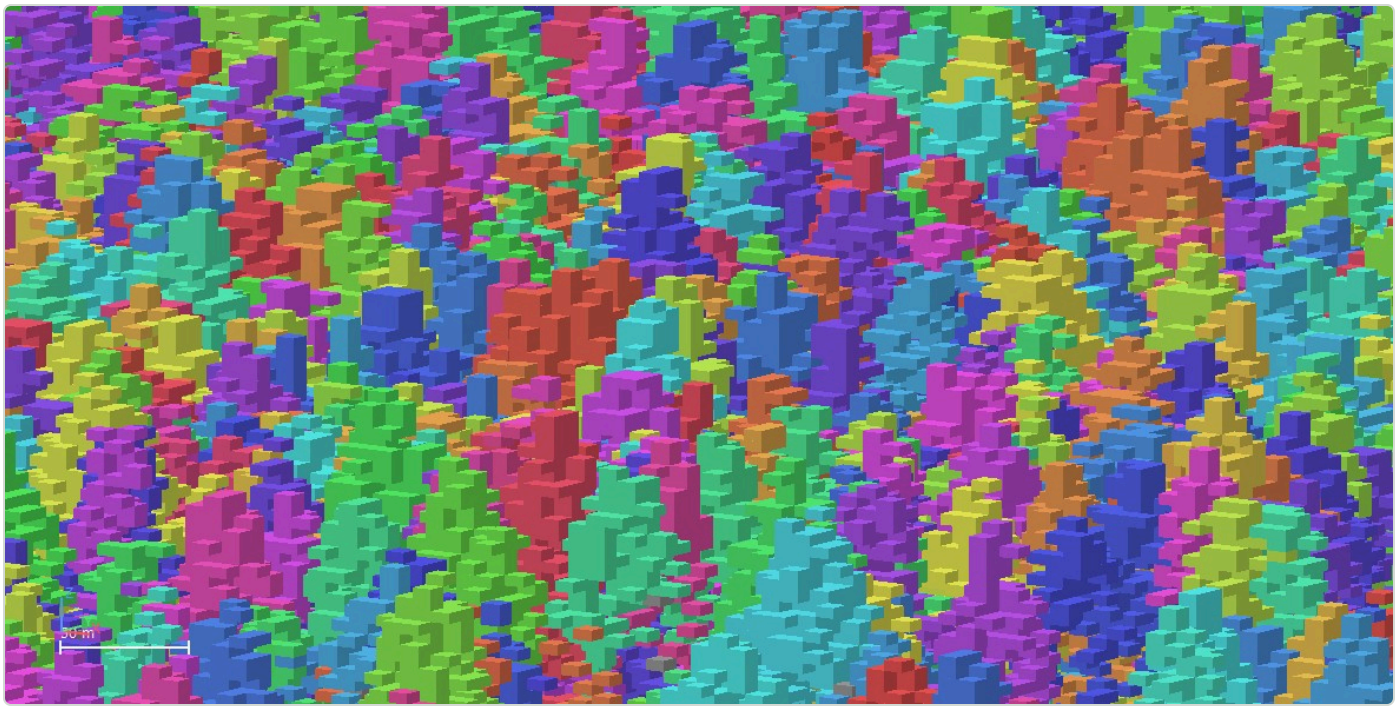
```
SilvaLiDARAirCLI.exe --tool grid-metrics --input-dir C:\SilvaLiDARAirExercise\01_Sites\01_CapitolStateForestWA\01_LAZ --output-dir C:\SilvaLiDARAirExercise\03_Projects\cli_out\voxels --voxel-xy 2 --voxel-z 1
```



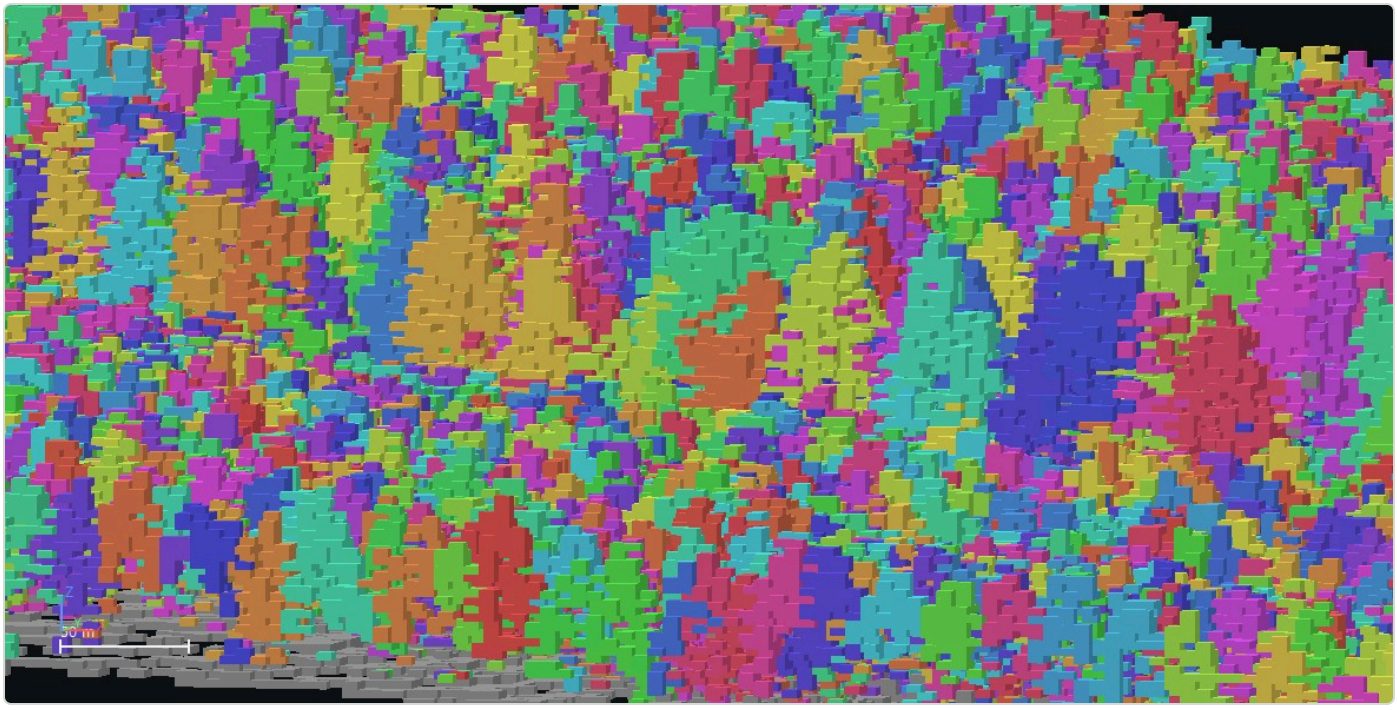
The window.



Voxel Metrics after tree detection, coloured by the tree most of each voxel's points belong to: the voxels of one tree share a colour.



The voxels close up, from the side (2 m × 1 m cells): each crown is a block of one colour, down its stem.

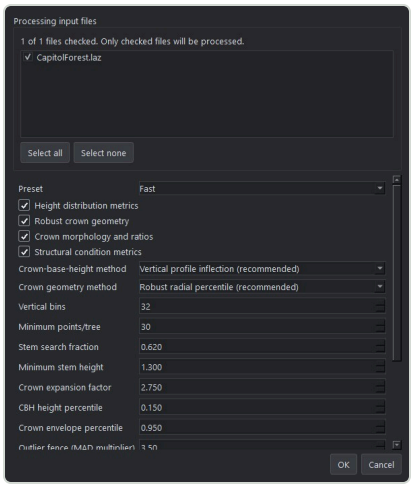


The voxels from the side: each tree is a column of voxels of one colour, from the crown down its stem.

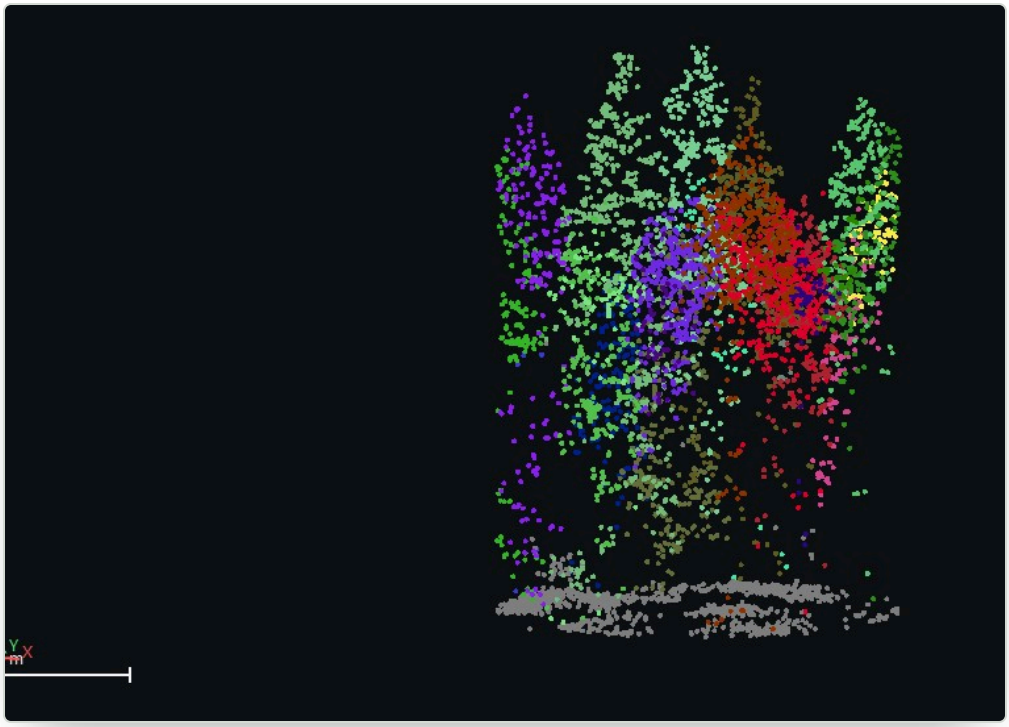
Individual Tree Metrics

Tools › Metrics › Individual Tree Metrics

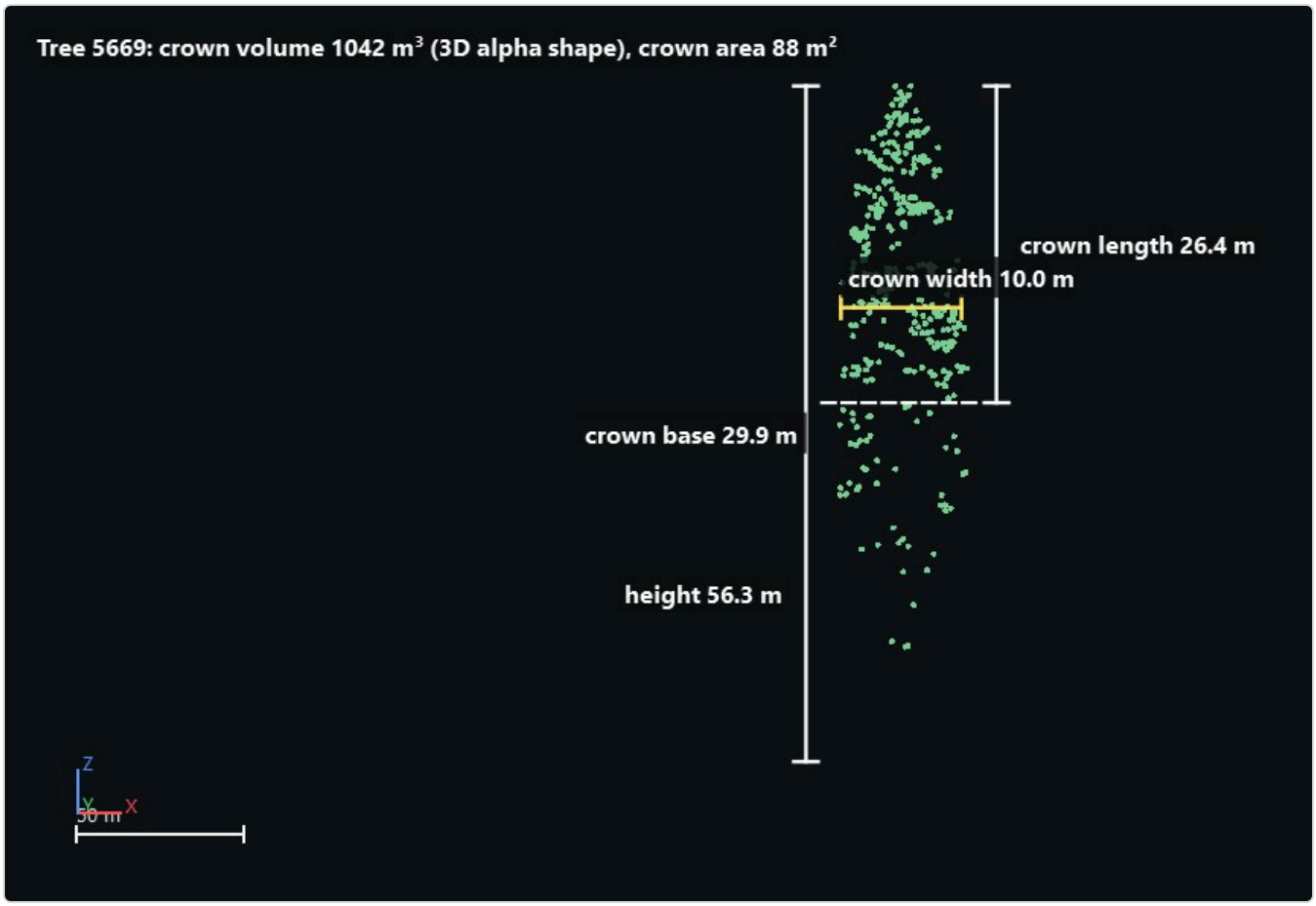
Height, crown and volume of every tree; optional 3D crown envelopes.



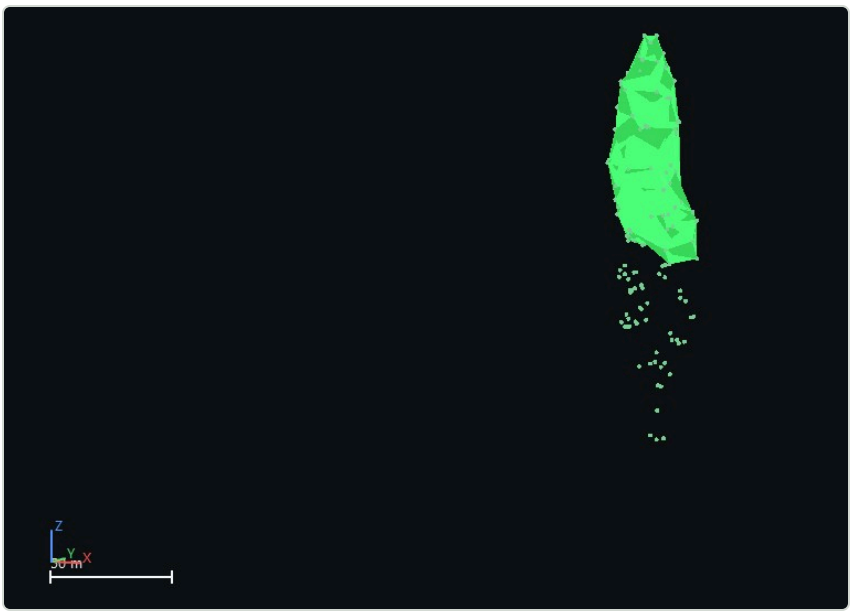
The window.



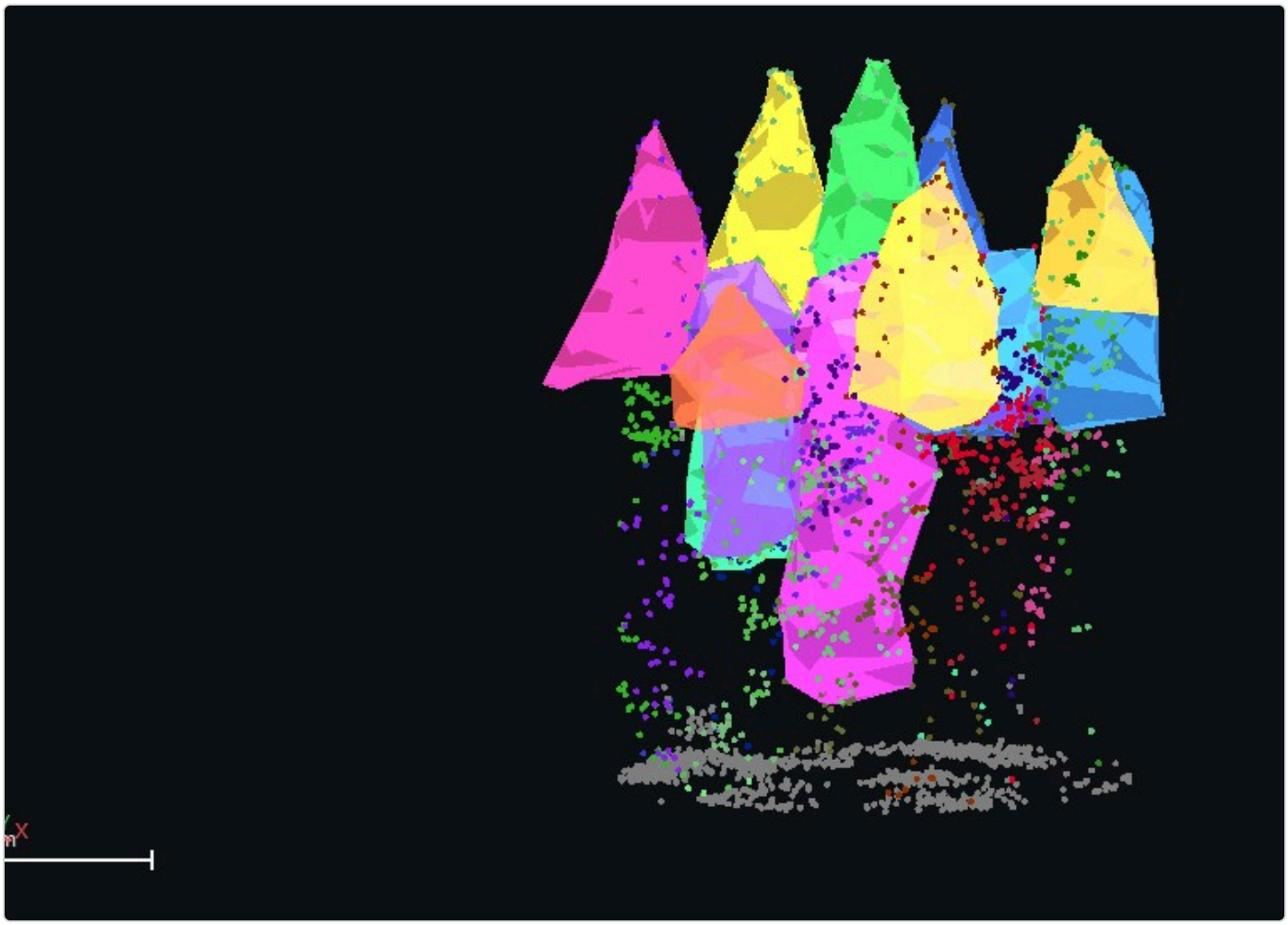
A few trees, each in its own colour (heights above ground): Individual Tree Metrics measures every one of them.



One tree alone (Tree ID display filter) with its metrics: height, crown base, crown length, crown width and crown volume.



The same tree with its 3D alpha-shape crown (Balanced mode, 3D volume and surface): the crown volume is the volume inside this surface.



The few trees with their alpha-shape crowns.

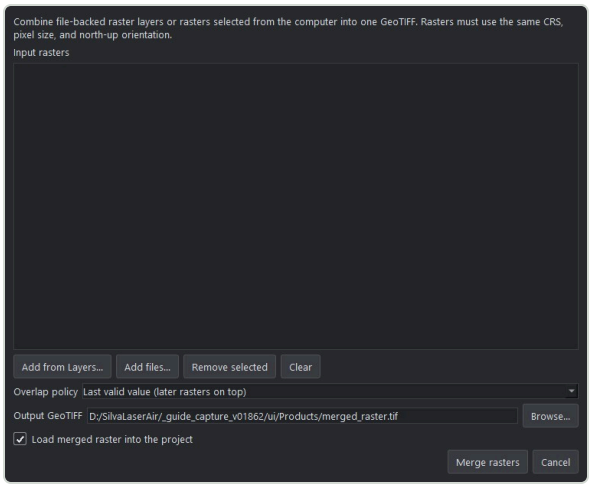
The first rows of the tree metrics table (one row per tree; the file has 37 columns).

tree	height	mean h	p95 h	crown base	crown length	crown ratio %	crown radius	crown area m²	condition
1	57.5	42.97	53.97	32.34	25.16	77.78	6.85	147.24	Snapped stem
2	56.63	42.46	52.44	33.62	23.01	68.42	6.93	150.68	Upright
3	56.23	41.22	53.22	29.87	26.36	88.24	7.09	157.96	Upright
4	56.19	42.89	52.71	29.85	26.34	88.24	7.02	154.91	Upright
5	56.13	42.64	53.32	31.58	24.56	77.78	7.03	155.14	Snapped stem
6	55.18	41.74	52.91	29.32	25.87	88.24	5.48	94.5	Upright

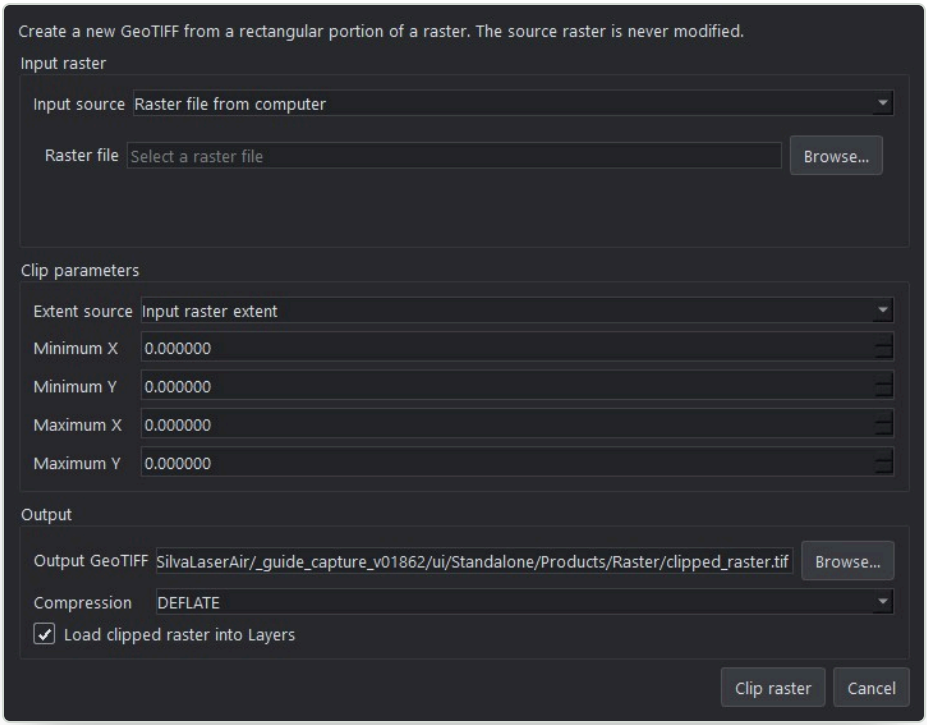
Raster tools

Tools › Raster

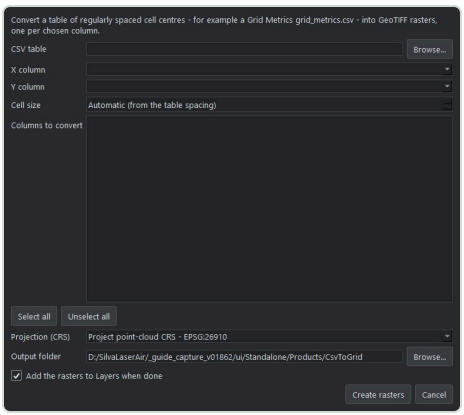
Merge, CSV to Grid, Clip, Assign CRS, Reproject.



The window.



The result on the example data.

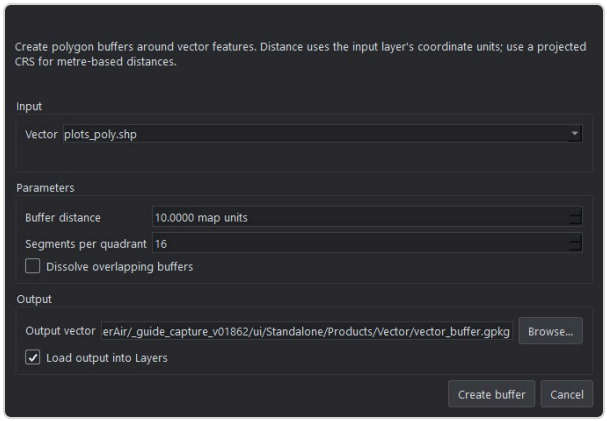


CSV to Grid makes a raster from a table of values.

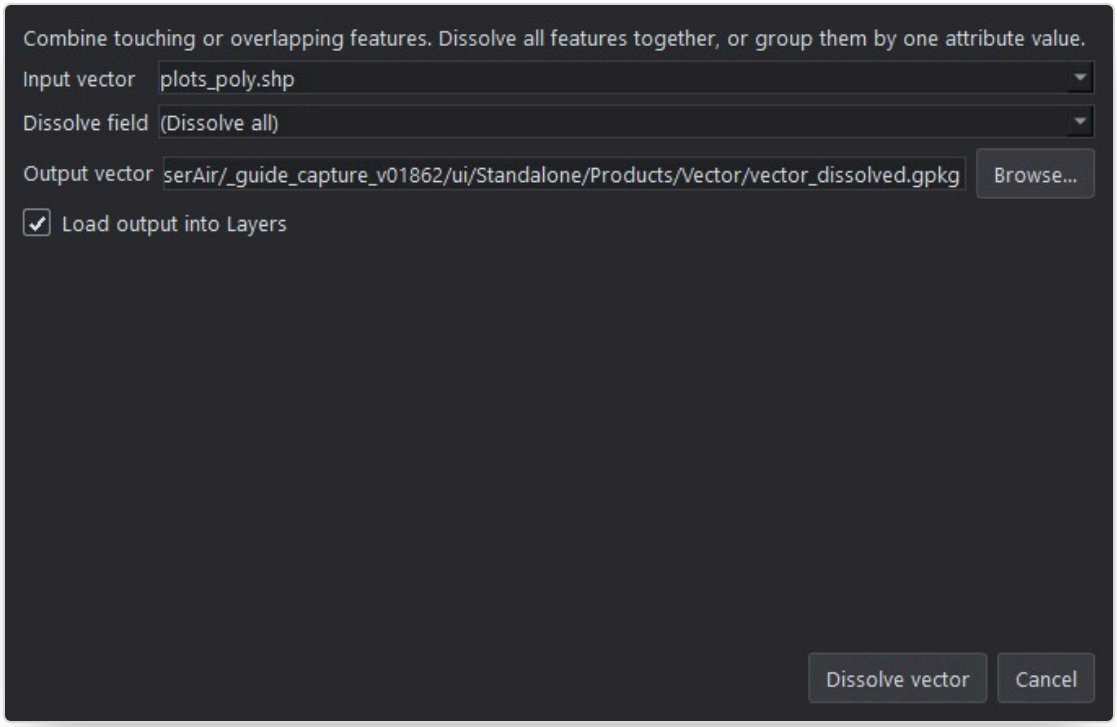
Vector tools

Tools › Vector

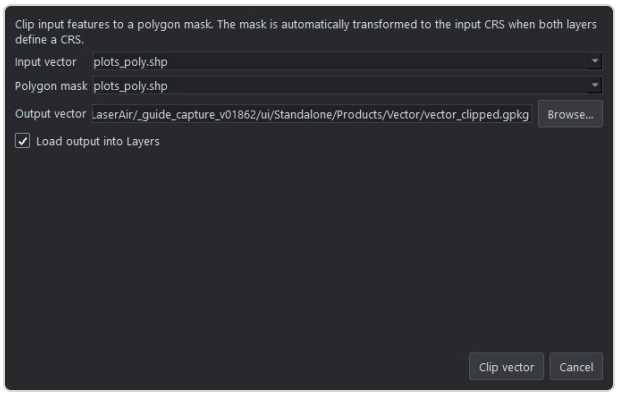
Merge, Buffer, Clip, Dissolve, Assign CRS, Reproject.



The window.



The result on the example data.

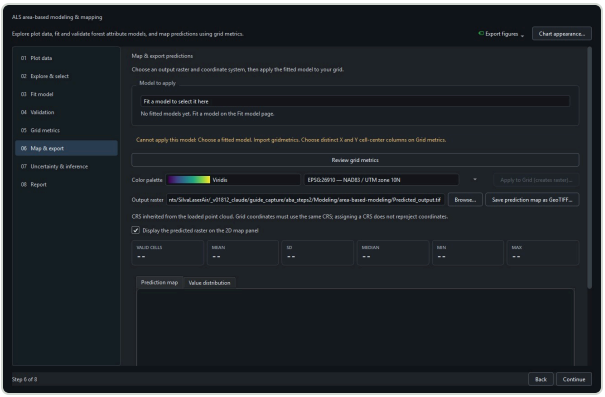


Clip Vector keeps the features inside a polygon layer.

Area-Based Modeling & Mapping

Tools › Modeling

From plot data and LiDAR metrics to validated models, maps, uncertainty and an HTML/PDF report.

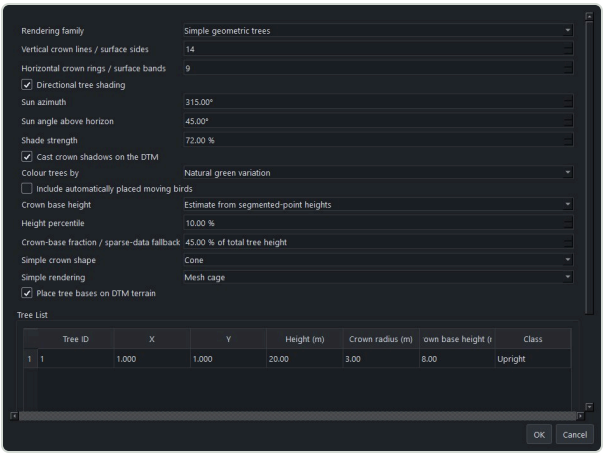


The window.

Create Virtual Forest

Tools › Virtual Forest

A 3D tree on every detected tree, sized to its height and crown, with optional birds: simple geometric trees, or realistic 3D models imported from GLB, glTF, OBJ, FBX and other files.



The window.

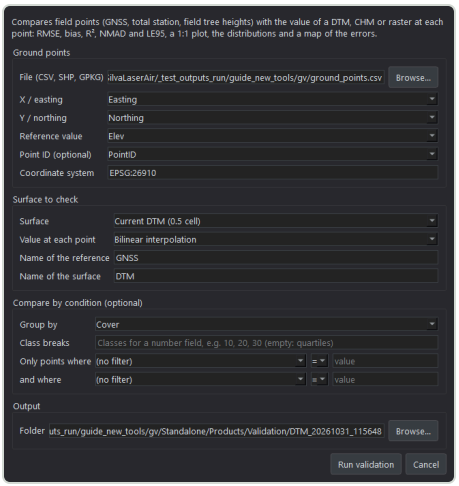


The result on the example data.

Validate with Ground Points

Tools › Raster › Validate with Ground Points…

Compares field points (GNSS or total-station ground points, field tree heights) with the value of a DTM, CHM or raster at each point, read by bilinear interpolation or from the nearest cell: bias, MAE, RMSE, NMAD, LE95 and R^2, overall and per group, with a 1:1 plot, the distributions, the differences and a map of the errors. Writes the figures, a CSV and a report in HTML and PDF. The example data has no surveyed ground points, so this guide shows the window only.

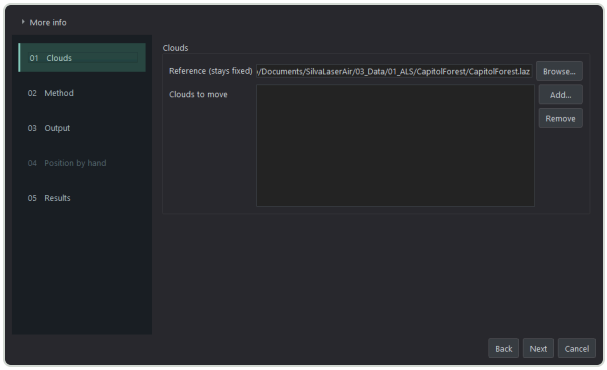


The window.

Align Point Clouds

Tools › Point Cloud › Align Point Clouds…

Moves clouds onto a reference: a coarse match of the terrain and canopy over every heading and shift, then a fine point-to-plane ICP on the ground and trunks; or position by hand first. Writes the aligned clouds with every point and attribute, each one's 4×4 matrix, optionally one merged file with each cloud's number in Point Source ID, and a report. Aligning needs a second cloud of the same area: see the Demonstrations, where drone, mobile and terrestrial scans of one plot are shown together.



The window.

Georeference with Targets

Tools › Point Cloud › Georeference with Targets…

Carries a cloud in local coordinates (TLS, MLS or drone) onto surveyed targets: pick each target (a point, the centre of the points around it, or a fitted sphere), give its known coordinates and coordinate system, and the rotation, shift and optional scale are fitted by least squares, with each target's residual. Writes LAS/LAZ with the coordinate system and a CSV of the targets. The example data has no surveyed targets, so this guide shows the window only.

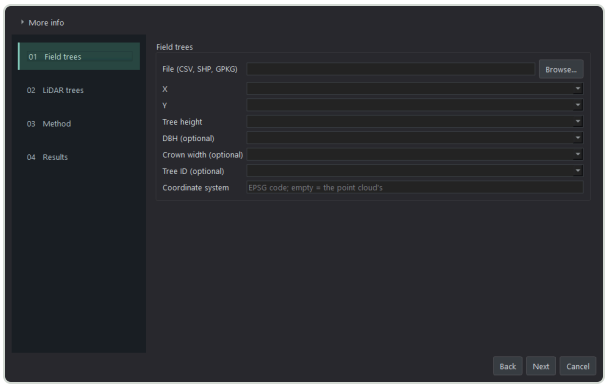


The window.

Match Field and LiDAR Trees

Tools › Canopy › Match Field and LiDAR Trees…

Pairs field-measured trees with the detected trees or a file of LiDAR trees: height-difference search (optionally the smallest Euclidean distance in X, Y, height and extra metrics you pair and weight), height-scaled 3D index, optimal pairing or nearest within a radius, with an optional search for the plot shift. Reports matched trees, omissions, commissions, recall, precision, F-score and the errors of the matched trees, with eight figures, matched_trees.csv and a report. The example data has no field-measured trees, so this guide shows the window only.



The window.

Export 3D Scene

File › Export 3D Scene (.glb)…

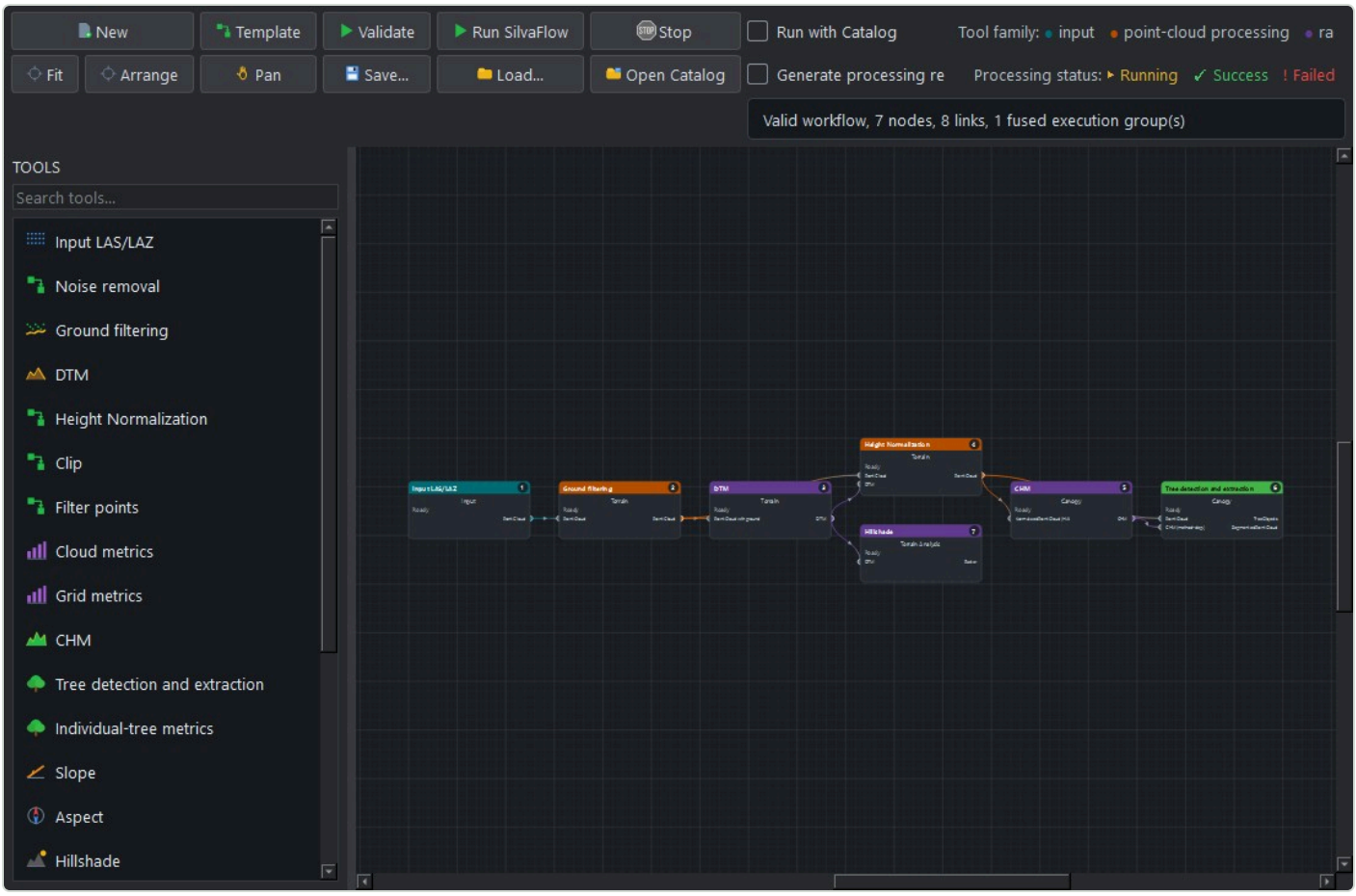
What the 3D Scene shows as one glTF binary file (.glb) for Blender (File › Import › glTF 2.0), Unity (glTFast package) or any program that reads glTF: the virtual forest (your 3D models or simple trees), the terrain (plain or coloured with a raster), the point cloud (in its displayed colours, thinned to a chosen number of points), vector layers and 3D crowns, each its own group. The displayed layers are ticked; tick or untick any. Each tree model is stored once and placed on every tree, with its textures; the scene is Y-up and moved to a local origin, written with the coordinate system in <name>_origin.txt.

Workflows, assistant and automation

SilvaFlow

SilvaFlow button

A graph editor: each box is a tool, each line passes results to the next. Save a workflow and run it again on new data; a re-run only recomputes what changed. Tick Generate processing report after run for the HTML/PDF report.

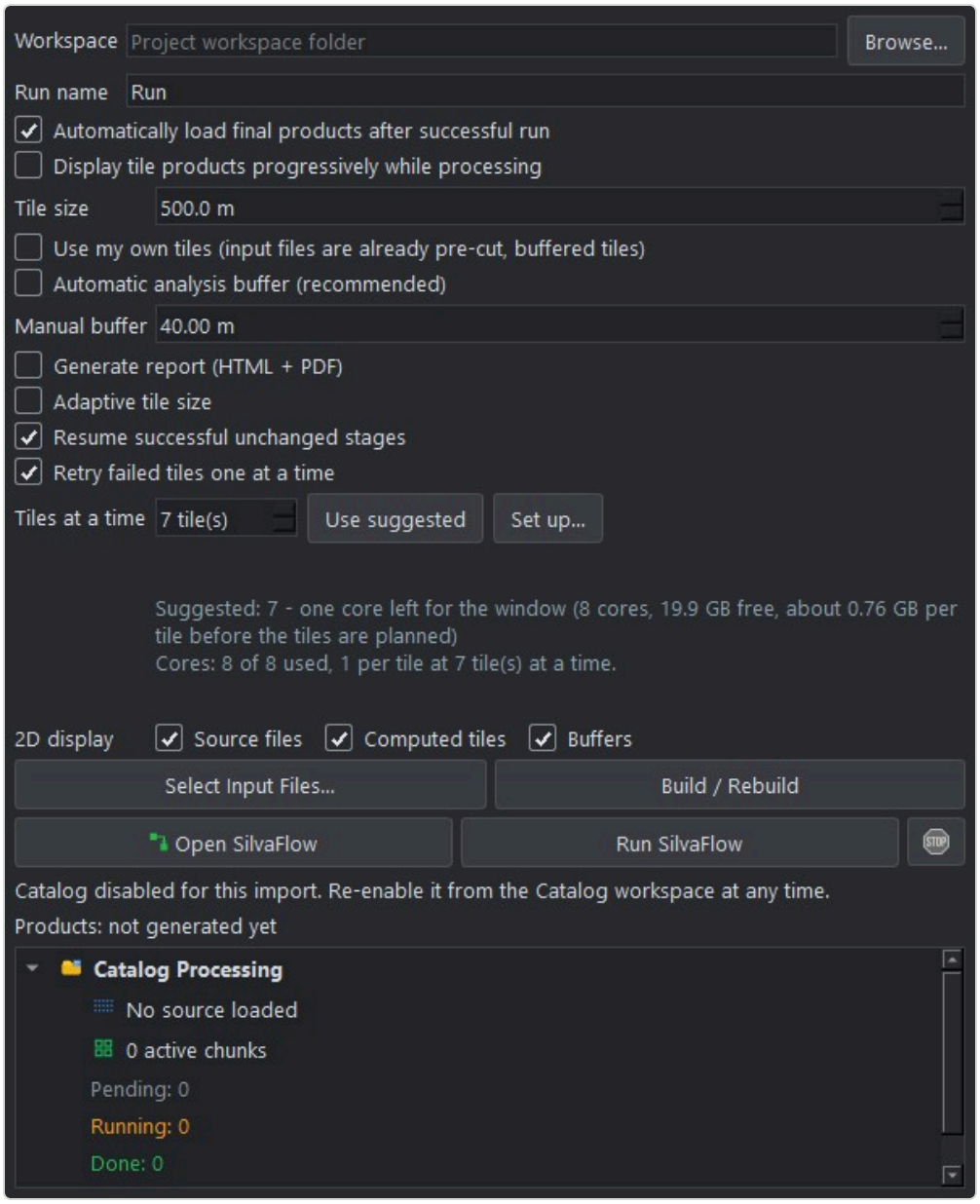


The SilvaFlow editor: the tool list on the left, the workflow boxes on the canvas.

SilvaFlow + Catalog

Catalog button

Runs a SilvaFlow tile by tile over areas of any size, with a buffer around each tile, several tiles at a time; merges the products and writes the report.

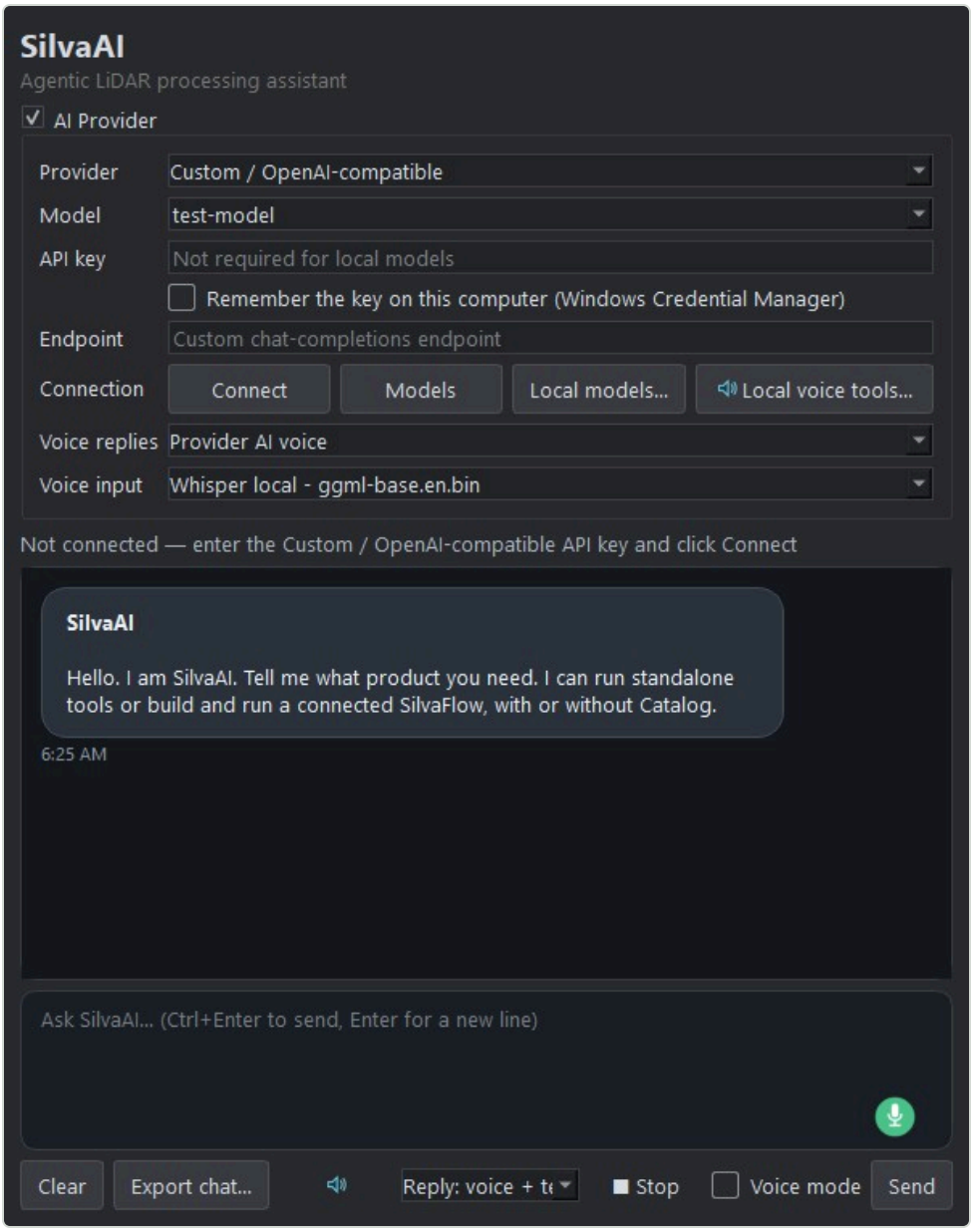


The Catalog settings: tile size, buffer and tiles at a time.

SilvaAI

SilvaAI button

An assistant that explains tools and builds and runs workflows from a plain request, with a local model (Ollama, offline) or your own key for OpenAI, Anthropic or Gemini; it can also talk by voice.



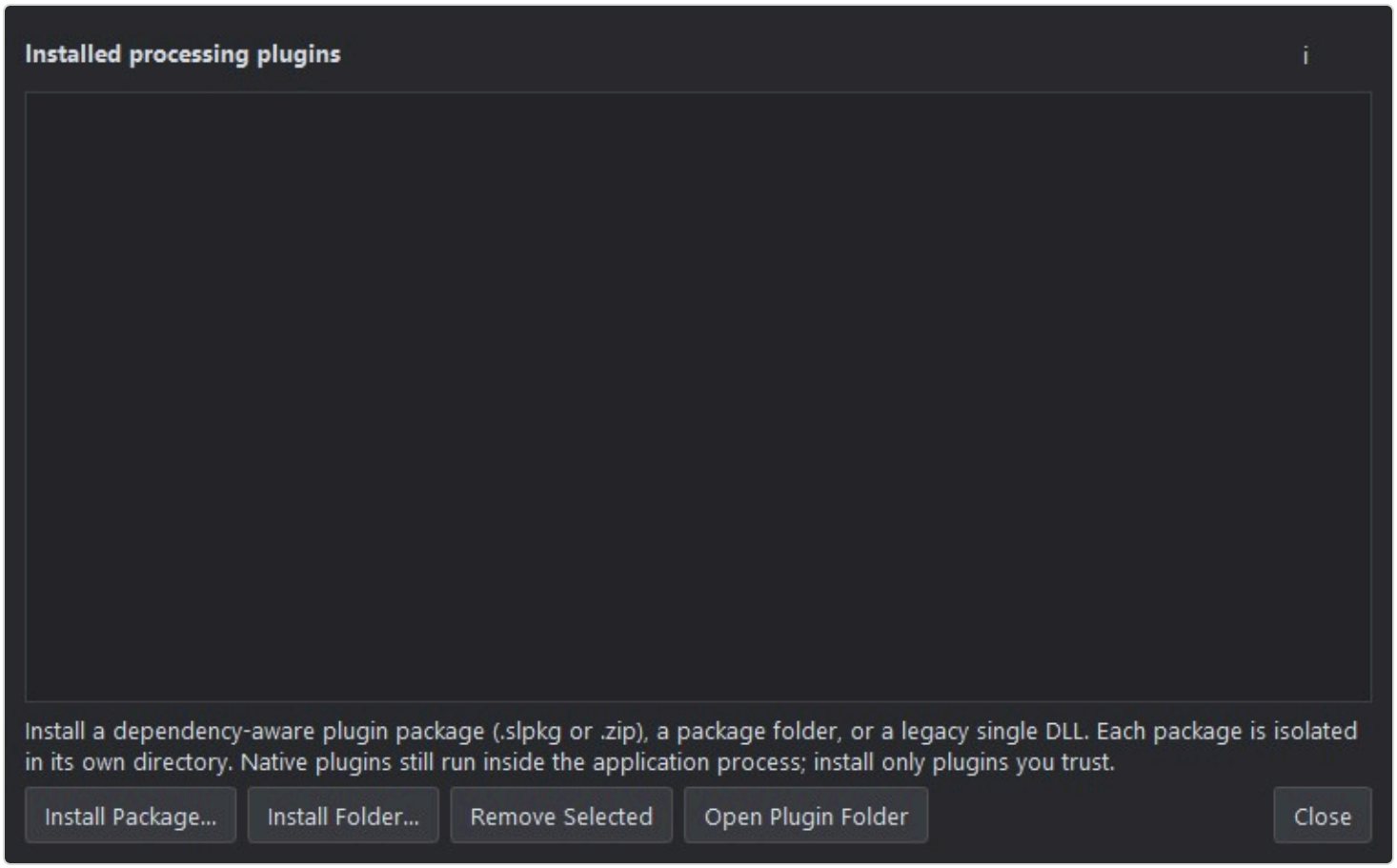
The SilvaAI panel: provider, model and the conversation.

- Messages and a summary of your project go to the provider you choose.

Plugins

Plugins menu

Plugins add new tools or new methods to built-in tools; Reload Plugins makes them available without restarting.



Manage Plugins.

AI clients (MCP)

SilvaLiDARAir.exe --mcp

Claude Desktop, Claude Code or any Model Context Protocol client can drive SilvaLiDAR Air: create projects, add data, build and run workflows (with Catalog), and read the status, log and products.

Command line

SilvaLiDARAirCLI.exe

The same engines without the window, for scripts and batch jobs. `SilvaLiDARAirCLI.exe --tool <name> --help` lists each tool's options. Every command in this guide was run on the example data with version 0.1.8.13.



PART 3

Exercises

Do the exercises in order: each one starts where the previous ended. Every exercise lists what you need and the major steps, then the procedure, with the pictures beside the steps. Verbs in *italics* are what you do; names in **bold** are what you see on screen.

The exercise data

All the data of the exercises are in one zip, **SilvaLiDARAirExercise.zip** (445 MB). ***Download*** it from https://github.com/carlos-alberto-silva/SilvaLiDAR-Air-data/releases/download/exercise-data-v1/SilvaLiDARAirExercise.zip, ***right-click*** it › **Extract All…** and ***extract*** it to **C:**, as Exercise 1 shows. The examples of this guide use the paths below; if you extract it somewhere else, change the paths to match.

The folders

```
C:\SilvaLiDARAirExercise
│   README.txt                    how to install the data, and this structure
│   Data_credits.txt              source, licence and citation of every dataset
├── 01_Sites                      the input data, one folder per site (never written to)
│   │   SiteEPSGCRSname.txt       the coordinate system (EPSG) of each site
│   ├── 01_CapitolStateForestWA   Exercises 1 to 14
│   │   ├── 01_LAZ                CapitolForest.laz (+ .lax index)
│   │   ├── 02_SHP                plots_poly.shp: 60 illustration plots
│   │   └── 03_Imagery            CapitolForest_Orthophoto.tif
│   ├── 02_AmazonBrazil           Exercise 9 and Demonstration B
│   │   ├── 01_LAZ                CAUL7780C9583.laz
│   │   ├── 02_SHP                Cauaxi_LoggingUnit.shp
│   │   └── 03_Metrics            plot metrics with field biomass, 20 m grid metrics
│   └── 03_ParisFrance            Demonstration C
│       └── 01_LAZ                Bois de Boulogne and central Paris, 1 km tiles (COPC)
├── 02_SilvaFlow                  SilvaFlow_ALS_processing_ABA.sfw: a ready-made workflow
└── 03_Projects                   your projects and the command-line outputs (cli_out)
```

Keep **01_Sites** as it is: SilvaLiDAR Air never writes beside the input data. Products, caches and logs go to the project folder you choose, here inside **03_Projects**.

The three sites

Site	Data	Coordinate system	Used in	Source and credit
Capitol State Forest, Washington, USA	Conifer forest (Douglas-fir) with harvest units and roads. Airborne LiDAR with RGB, 4.86 million returns over about 120 ha; 60 random illustration plots; an RGB orthophoto.	EPSG:26910 NAD83 / UTM 10N	Exercises 1–14	FUSION/LDV sample data, USDA Forest Service (forsys.sefs.uw.edu/fusion).
Fazenda Cauaxi, Pará, Brazil	Selectively logged tropical forest. Airborne LiDAR, 35.2 million returns over about 0.86 × 0.77 km; the logging unit; LiDAR metrics of 85 field plots with field biomass (TAGBn) and of every 20 m cell.	EPSG:31982 SIRGAS 2000 / UTM 22S	Exercise 9, Demonstration B	Sustainable Landscapes Brazil Project (USAID, US Department of State, EMBRAPA, US Forest Service). Silva et al. (2017), Remote Sens. 9, 1068, doi.org/10.3390/rs9101068.
Paris, France	Two classified 1 km tiles of the French national LiDAR: the Bois de Boulogne park (20.2 million returns) and central Paris (14.6 million returns), flown in 2023.	EPSG:2154 RGF93 v1 / Lambert-93 heights IGN69	Demonstration C	© IGN – LiDAR HD, Etalab Open Licence 2.0 (geoservices.ign.fr/lidarhd).

Every point cloud carries its coordinate system in its header, so SilvaLiDAR Air places each site on the map as it opens; **01_Sites\SiteEPSGCRSname.txt** lists them. **Data_credits.txt** in the zip gives the full credit and the citation of each dataset: please cite them when you use the data.

02 EXERCISE 2
GETTING STARTED WITH SILVALIDAR AIR

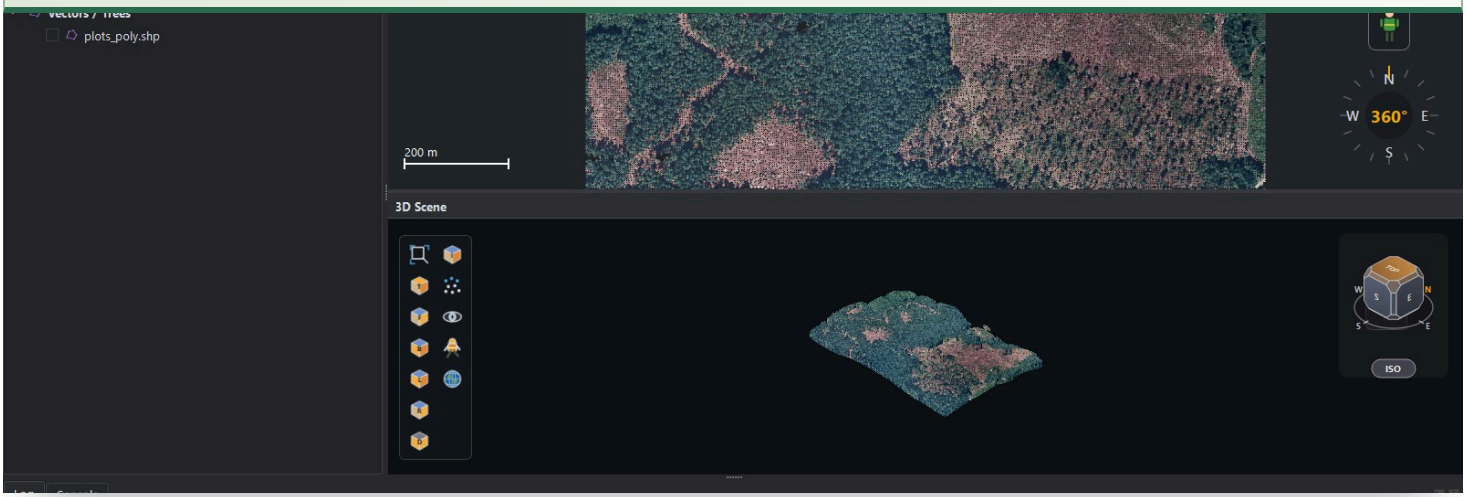


Figure 2.1 What you will make in this exercise.

Introduction

In this exercise you load the example point cloud, find your way around the window, and explore the data in the 2D map and the 3D scene.

You will learn to

- ✓ Import a point cloud and a vector layer
- ✓ Name the parts of the window
- ✓ Move around the 2D map and the 3D scene
- ✓ Colour the points by RGB, elevation, intensity and class

Prerequisites

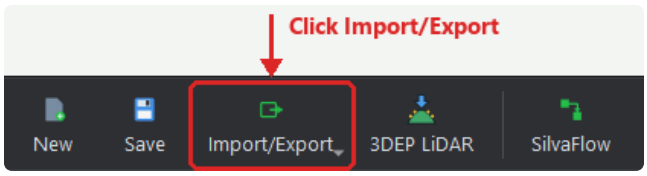
- Exercise 1

Overview of major steps

1. Import the point cloud
2. Learn the parts of the window
3. Navigate the 2D map
4. Navigate the 3D scene
5. Change how the points are coloured

Procedure

Part 1: Import the example data



1. *Click* **Import/Export** › **Import…**, *select* **CapitolForest.laz** and *Click* **Open**.
2. The **Open LAS File** window lists the attributes in the file. Keep them all ticked and *Click* **Apply**.

3. The **Global shift** window offers to move the coordinates near zero for display. *Click* **Yes**: the shift is undone whenever you export.
4. The cloud opens in the **3D Scene** and is listed in the **Data** panel.

> **Tip** Import Folder… opens every LAS/LAZ of a folder as one collection; very large data open as a streamed collection that reads only what you look at.

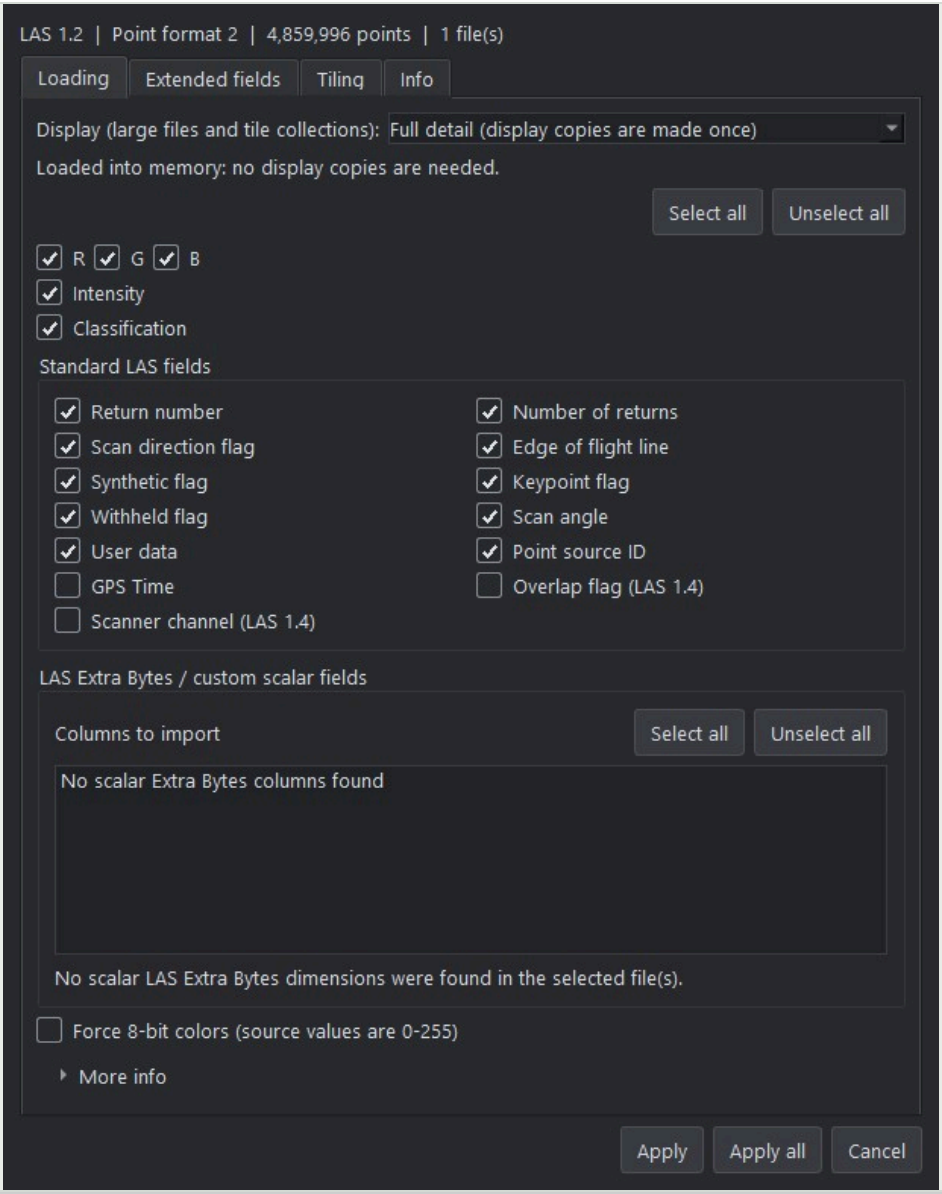


Figure 2.2 Open LAS File: the attributes to load.

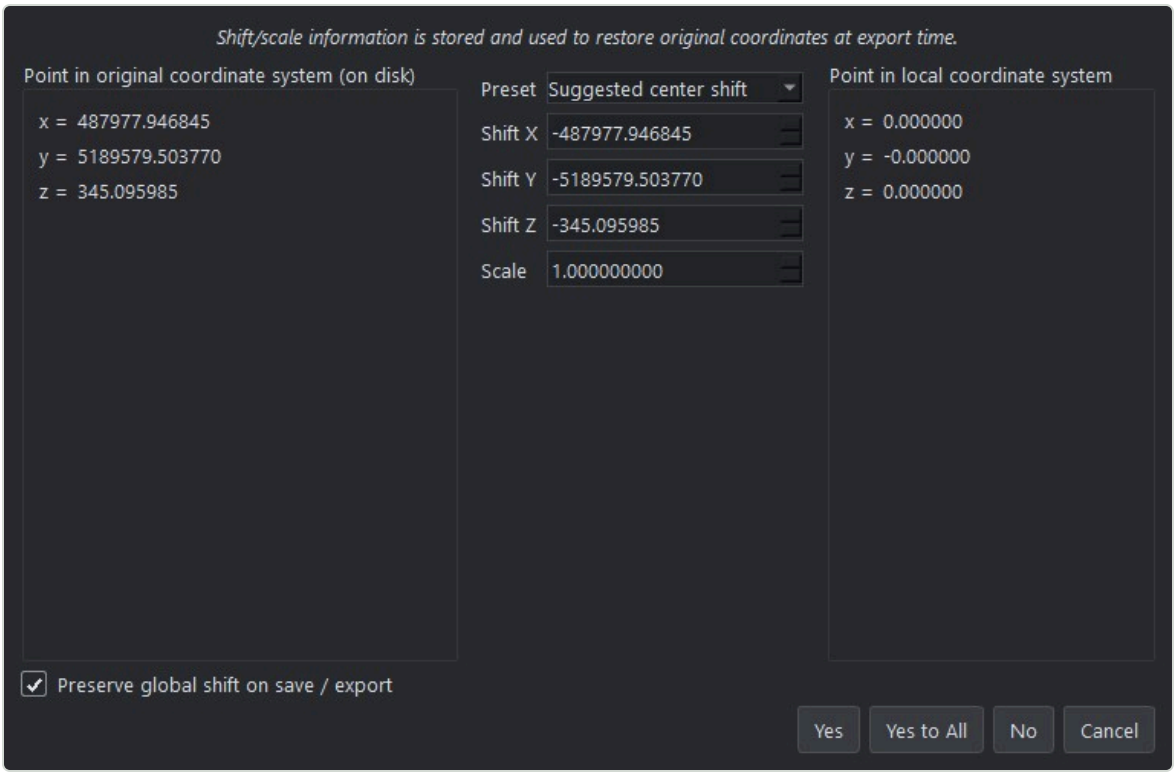


Figure 2.3 Global shift: keeps full precision in the views.

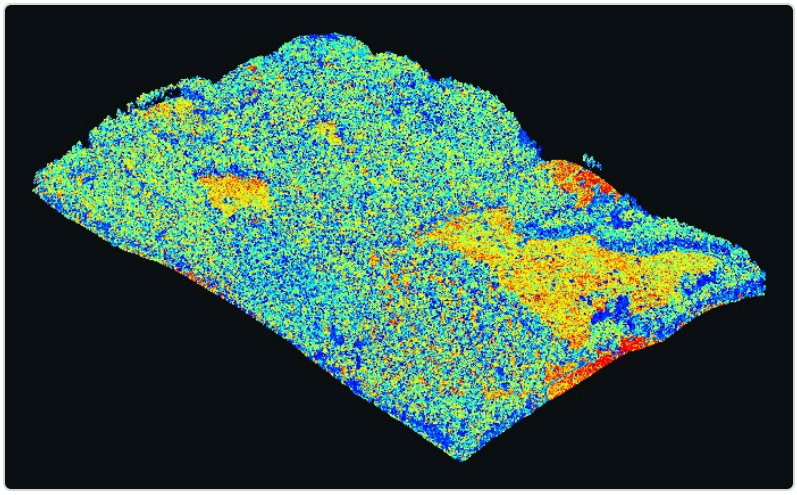


Figure 2.4 The cloud coloured by intensity.

Part 2: The parts of the window

1. Find each part of the window shown on the left: the **menus**, the **toolbar**, the **Data** / **Products** / **Reports** panel, the **2D** / **3D Scene**, the **Log and Console**, and the **status bar**.
2. *Look* at the status bar: it shows the coordinate system of the data, **EPSG:26910 (NAD83 / UTM zone 10N)**.
3. *Untick* and *tick* **CapitolForest.laz** in the Data panel to hide and show it.

> **Note The interface** in Part 1 explains every toolbar button and menu item.

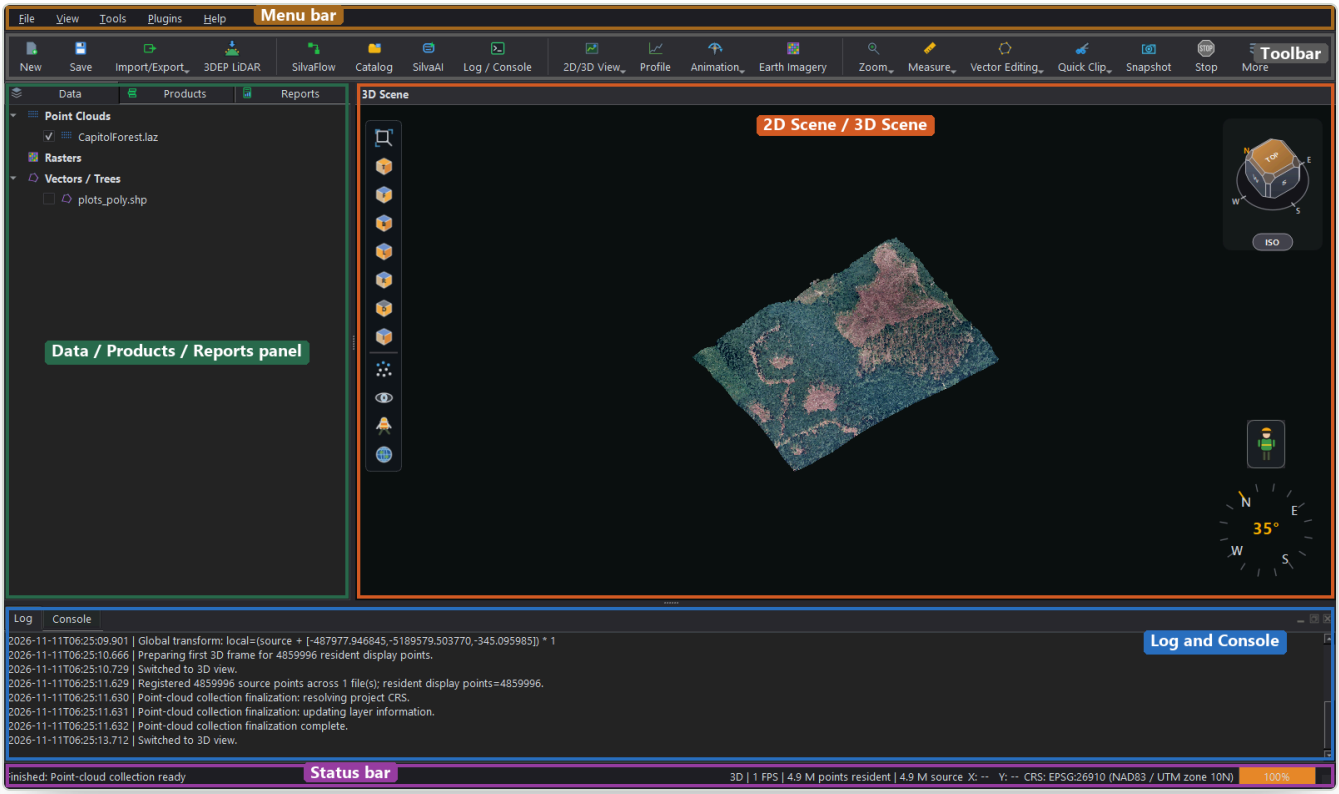


Figure 2.5 The parts of the window.

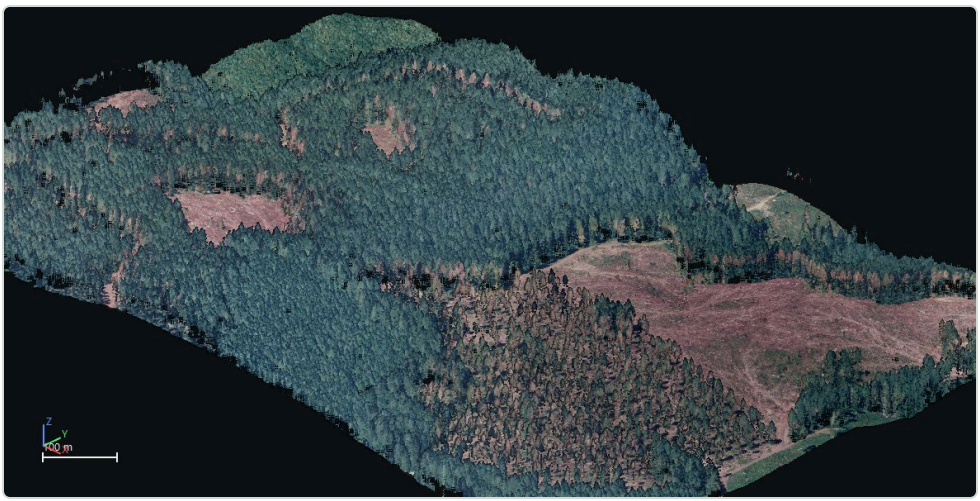
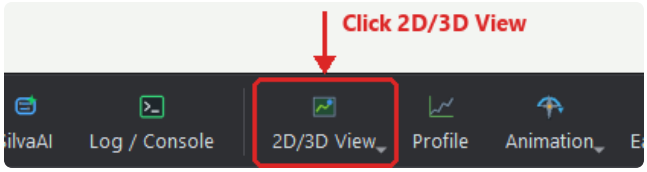


Figure 2.6 Eye-Dome Lighting shades the points by depth.

Part 3: The 2D map



1. *Click* **2D/3D View** › **2D Map**.
2. *Roll* the mouse wheel to zoom and *drag* to pan. **Zoom** › **Full Extent** shows all the data again.
3. The forester and the compass sit at the bottom right of the map.

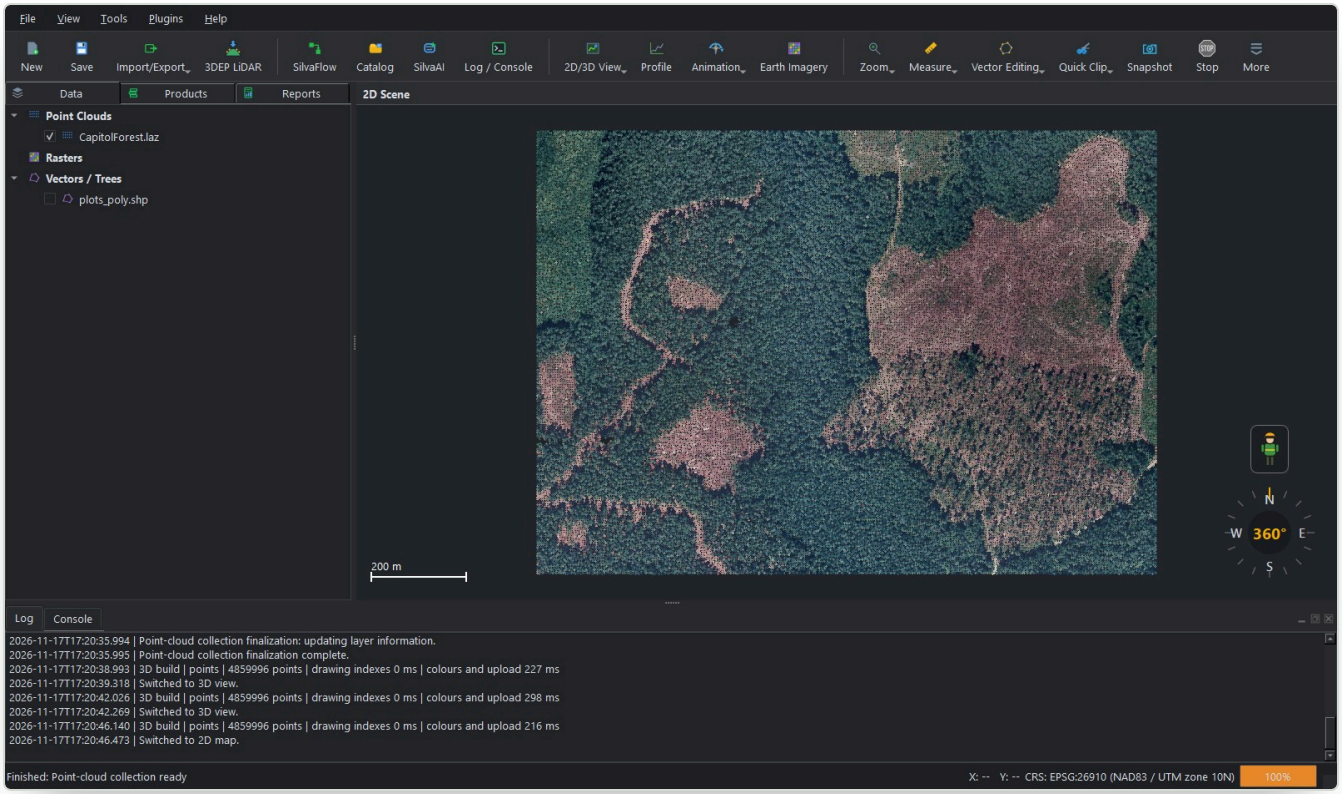


Figure 2.7 The 2D map of the point cloud.

Part 4: The 3D scene

1. *Click* **2D/3D View** › **3D View**.
2. *Drag* with the left button to orbit, *Shift-drag* to pan, *roll* the wheel to zoom.
3. *Click* **TOP** on the view cube, then **ISO**. *Try* the view buttons on the left edge of the scene (front, back, left, right).
4. *Click* the eye button (**Eye-Dome Lighting**): the points are shaded by depth and the relief reads more clearly.
5. *Click* **2D/3D View** › **Split View** to see both at once.

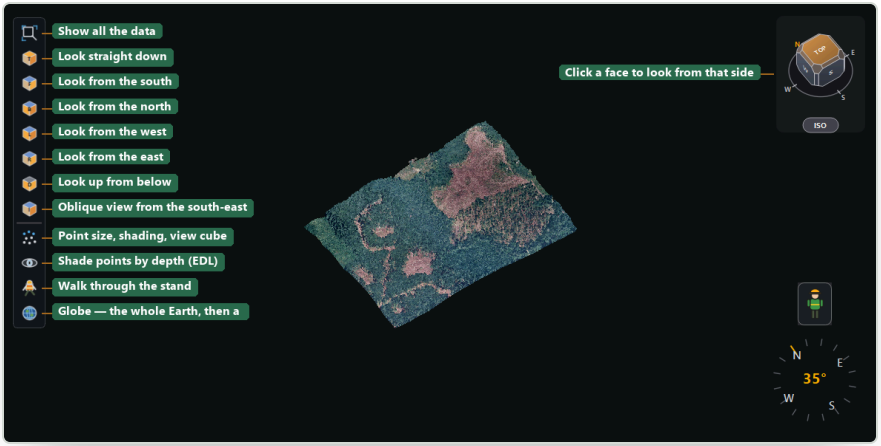


Figure 2.8 The controls of the 3D scene.

Part 5: Colour the points

1. *Right-click* **CapitolForest.laz** in the Data panel › **Properties**.
2. *Change* the colour mode from **RGB** to **Elevation**, then to **Intensity** and **Classification**. The legend follows.
3. *Set* it back to **RGB**.

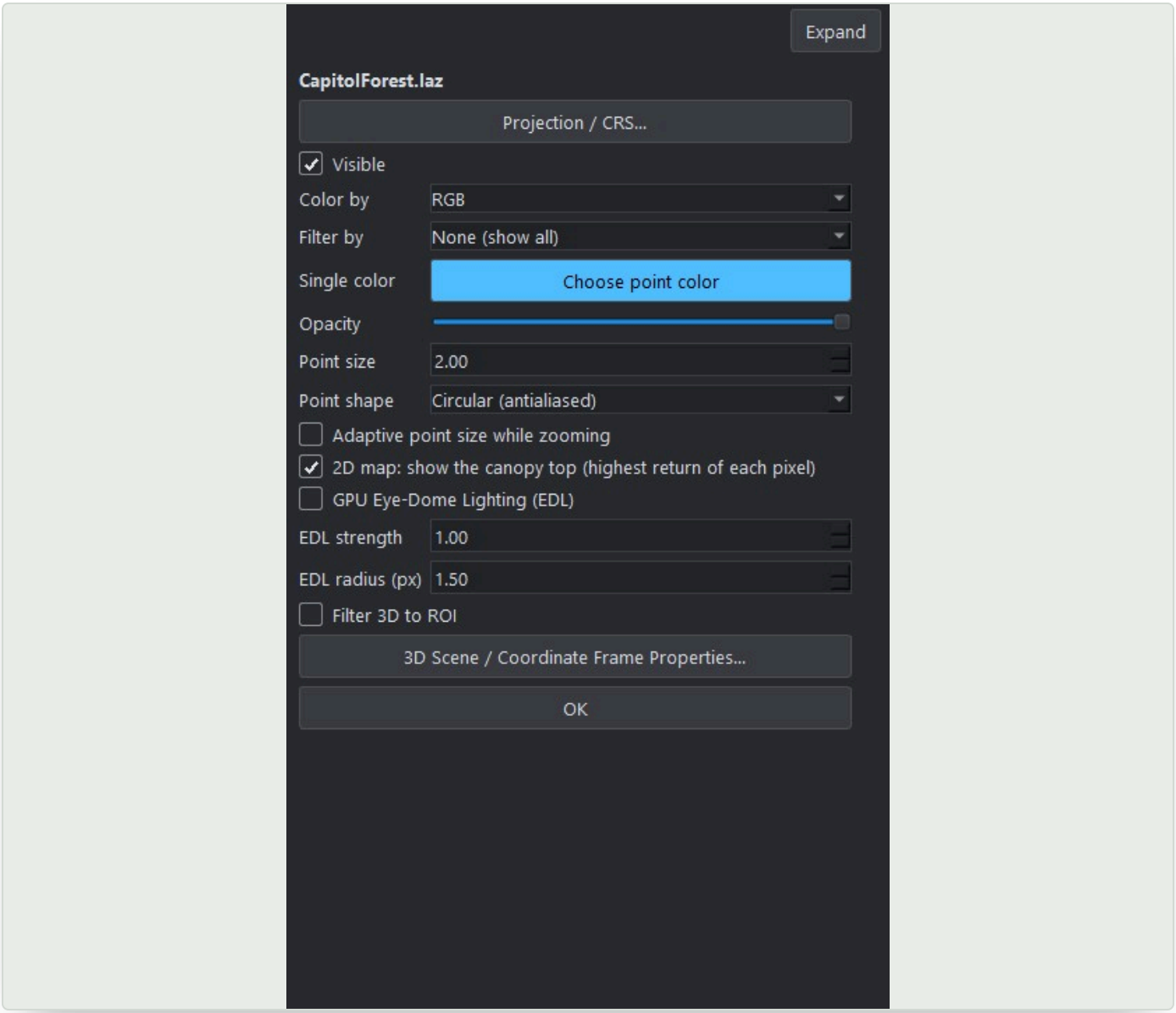


Figure 2.9 Properties of the point cloud.

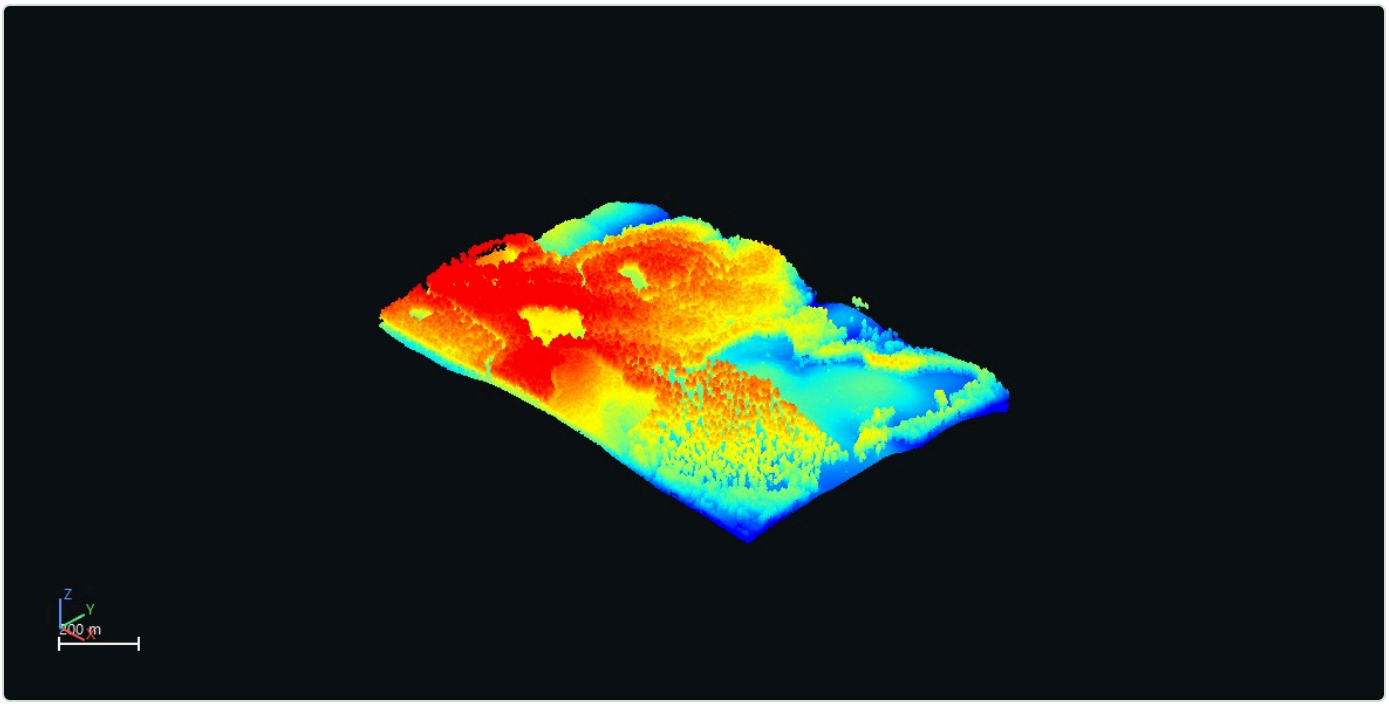


Figure 2.10 Coloured by elevation.

Result You can load data, move around the 2D map and the 3D scene, and change how the points are drawn.

Did you know? The global shift moves large UTM coordinates near zero for display only. Exports restore the original coordinates exactly.

Check your understanding

1. Why are UTM coordinates shifted for display?
2. Which colour mode shows the ground best? Which one shows the edges of the harvest units?
3. What does Eye-Dome Lighting add to the 3D view?

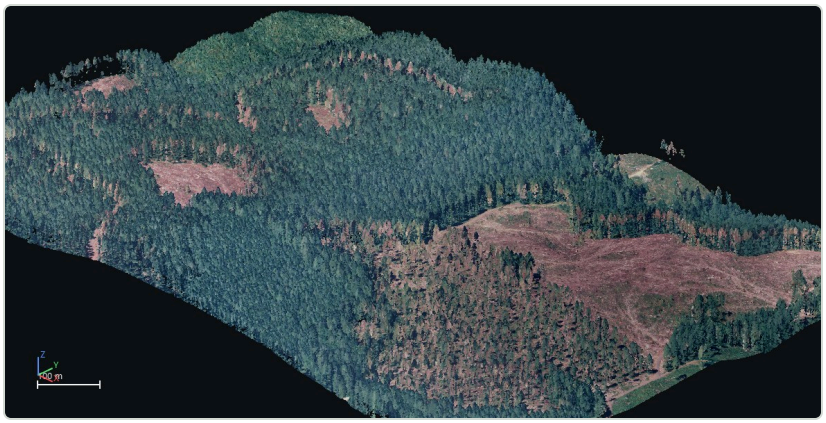


Figure 2.11 Eye-Dome Lighting off: the same points without depth shading.

03 EXERCISE 3 MEASURING AND PROFILES

SilvaLiDAR Air 0.1.8.80

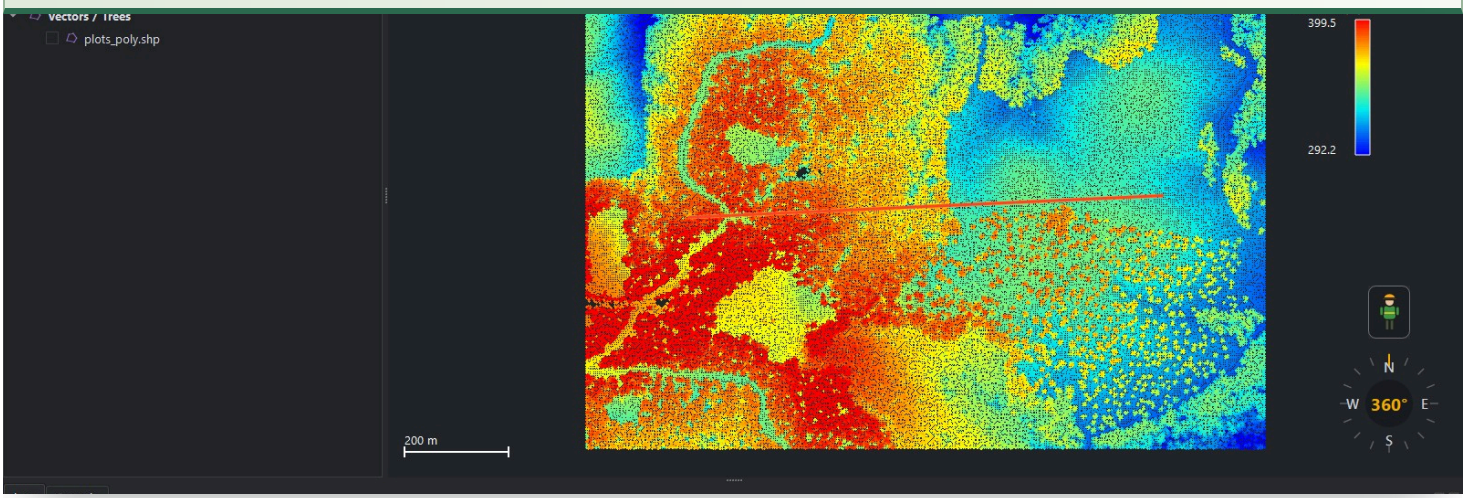


Figure 3.1 What you will make in this exercise.

Introduction

In this exercise you measure distances, heights and areas, and look inside the forest with a profile.

You will learn to

- ✓ Measure distances and areas on the map
- ✓ Measure the height of a tree in 3D
- ✓ Read the structure of the stand in a profile

Prerequisites

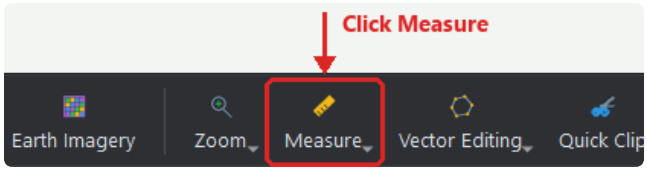
- Exercise 2 (the example cloud loaded)

Overview of major steps

1. Measure a horizontal distance
2. Measure a tree's height
3. Measure an area
4. Draw and move a profile
5. Colour the profile

Procedure

Part 1: Distance and area on the map



1. *Click* **Measure** › **2D Horizontal Distance** and *click* two points on the map. The distance is shown along the line.
2. *Click* **Measure** › **Area + Perimeter**, *click* the corners of an opening and *double-click* to finish.
3. *Click* **Measure** › **Clear Measurements and Drawings**.

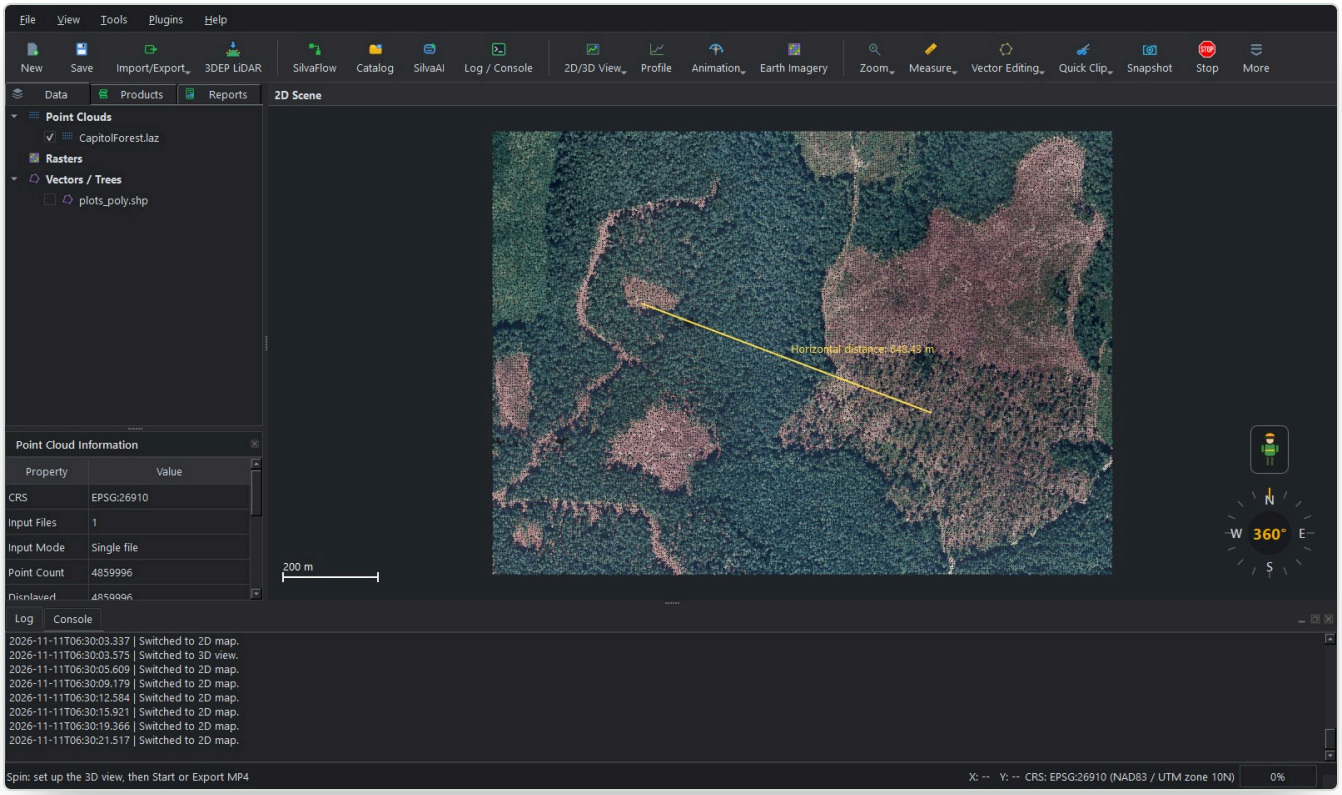


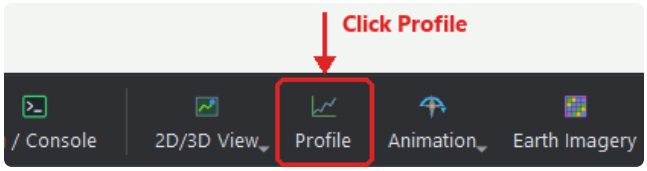
Figure 3.2 A horizontal distance on the map.

Part 2: The height of a tree

1. *Switch* to the 3D scene and *zoom* in on a tall tree.
2. *Click* **Measure** › **Vertical Height**, then *click* the top of the tree and a ground point beside it.
3. *Click* **Measure** › **Point Query** and *click* a point to read its coordinates, class and other attributes.

> **Tip** The tallest Douglas-firs of this stand are about 60–70 m tall.

Part 3: A profile



1. *Click* **Profile** and *click* two points across the stand on the 2D map.
2. The **Point Cloud Profile** panel opens with the slice of points along the line: ground, stems and crowns.
3. *Change* the **width** of the slice; *drag* the line or its ends on the map and the profile follows.
4. *Use* **Export** in the panel to save the profile as a picture.



Figure 3.3 The profile panel, coloured by elevation.

Part 4: Colour the profile

1. The profile uses the colours of the 3D scene. *Change* the colour mode of **CapitolForest.laz** (**Properties**, Exercise 2) and the profile follows, with its legend.
2. **Elevation** shows the slope of the ground and the height of the crowns; **Intensity** separates bright returns (bare ground, roads) from dark ones.
3. After ground filtering (Exercise 5) *colour* by **Classification**: the ground returns (class 2) run under the vegetation.
4. After tree detection (Exercise 7) *colour* by **Tree ID** and *draw* a short line: each crown has its own colour.

> **Tip** *Use* **Move -** and **Move +** in the panel to slide the line across the stand and watch the profile change.



Figure 3.4 Coloured by classification: ground under the vegetation.

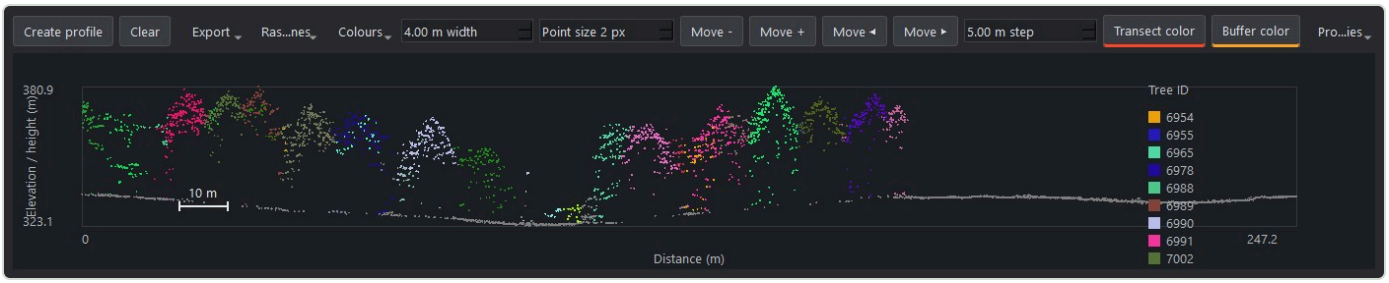


Figure 3.5 Coloured by tree ID along a short line: one colour per crown.

Result You can measure distances, heights and areas and read the structure of the forest in a profile.

Did you know? The profile follows its line live: drag the line or its ends on the map and the panel redraws as you move.

Check your understanding

1. How tall is the tallest tree you can find? Compare Vertical Height with the profile.
2. What changes in the profile when you double its width?

04 EXERCISE 4
CLIPPING THE LIDAR POINT CLOUD

SilvaLiDAR Air 0.1.8.80

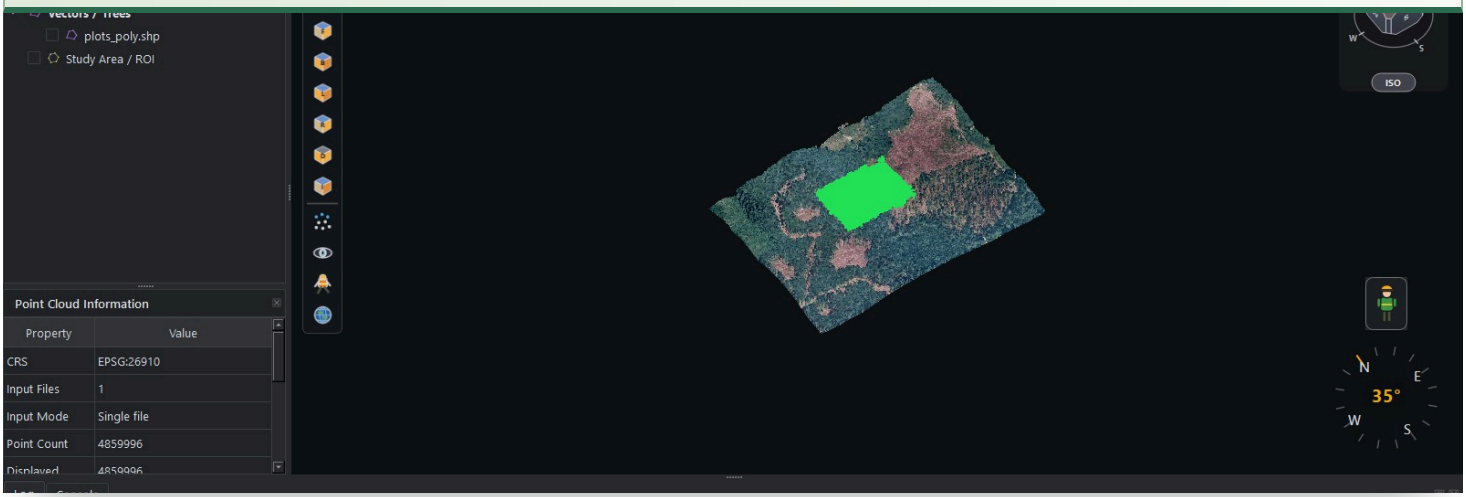


Figure 4.1 What you will make in this exercise.

Introduction

In this exercise you cut out an area with Quick Clip, keep it as a new layer, and clip the cloud by the plot polygons.

You will learn to

- ✓ Preview and apply a Quick Clip
- ✓ Keep a clip as a LAZ file
- ✓ Clip the cloud by plot polygons

Prerequisites

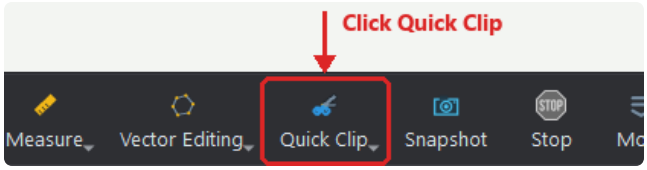
- Exercise 2

Overview of major steps

1. Quick Clip a box
2. Save the clip as LAZ
3. Load the plots and clip the cloud by them

Procedure

Part 1: Quick Clip



1. *Show* the 2D map. *Click* **Quick Clip** › **Clip IN box**.
2. *Click* two opposite corners of an area. The selection is previewed in green (kept) on the map and in 3D.
3. *Click* **Apply** on the floating bar. A clip layer appears in the Data panel.
4. *Try* **3D Clip IN polygon (Segment)**: *draw* around a single tree directly in the 3D scene.

Note Clip OUT removes the selection instead of keeping it. Nothing is removed from your file.

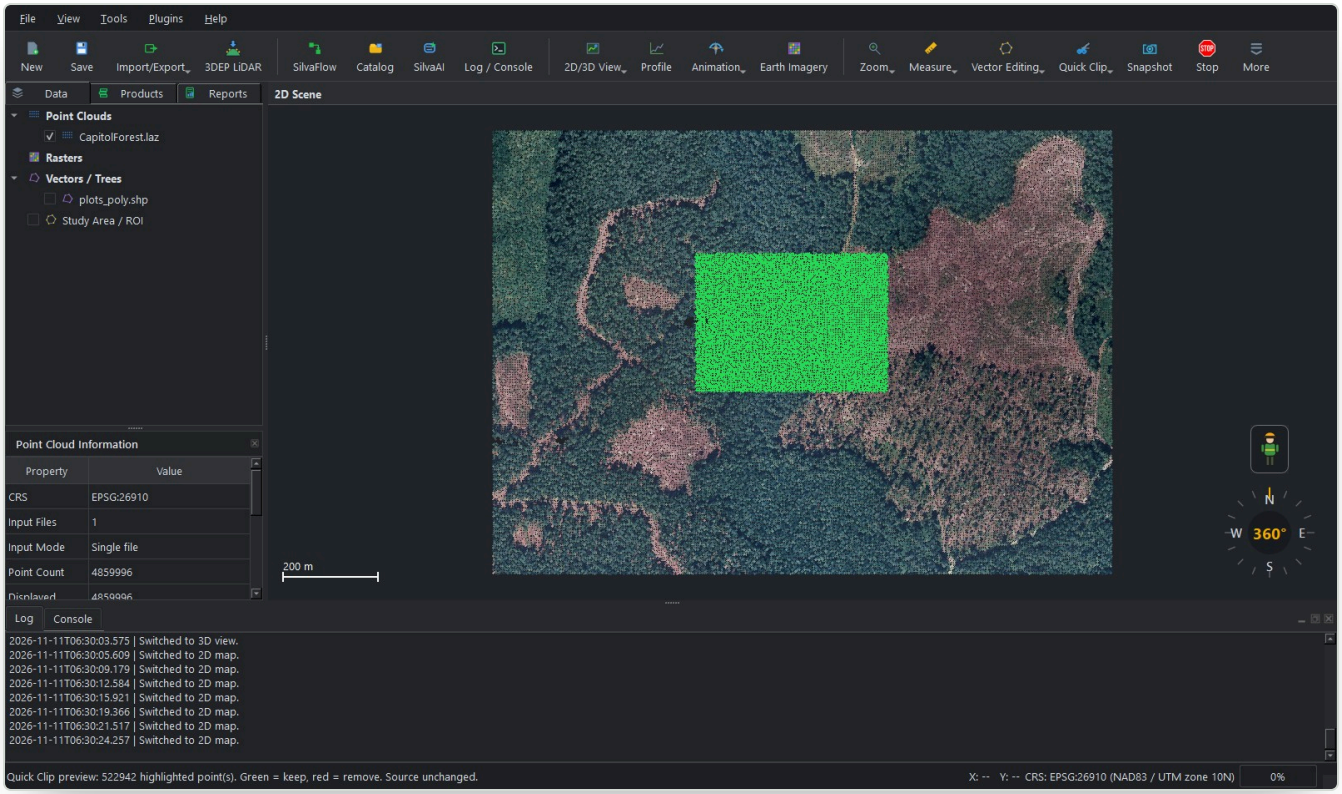


Figure 4.2 A Clip IN box previewed on the map.

Part 2: Keep the clip

1. *Right-click* the clip layer › **Save this layer as LAS/LAZ…**.
2. *Save* it as **C:\SilvaLiDARAirExercise\03_Projects\cli_out\clip_box.laz**.

Important Quick Clip layers are temporary and are deleted when SilvaLiDAR Air closes. Save the ones you want to keep.

Part 3: Clip by the plots

1. *Click* **Import/Export** › **Import…** and *select* **plots_poly.shp**: the 60 plots are drawn over the cloud and listed under **Vectors / Trees**.
2. *Open* **Tools** › **Point Cloud** › **Clip Point Cloud**.
3. *Choose* **plots_poly.shp** as the clip layer and **Id** as the name field.
4. *Set* the output folder to **C:\SilvaLiDARAirExercise\03_Projects\cli_out\plots** and *Click* **OK**. One LAZ is written for each plot.

Tip For a shapefile of plot centres, the window asks for a circular or square plot size.

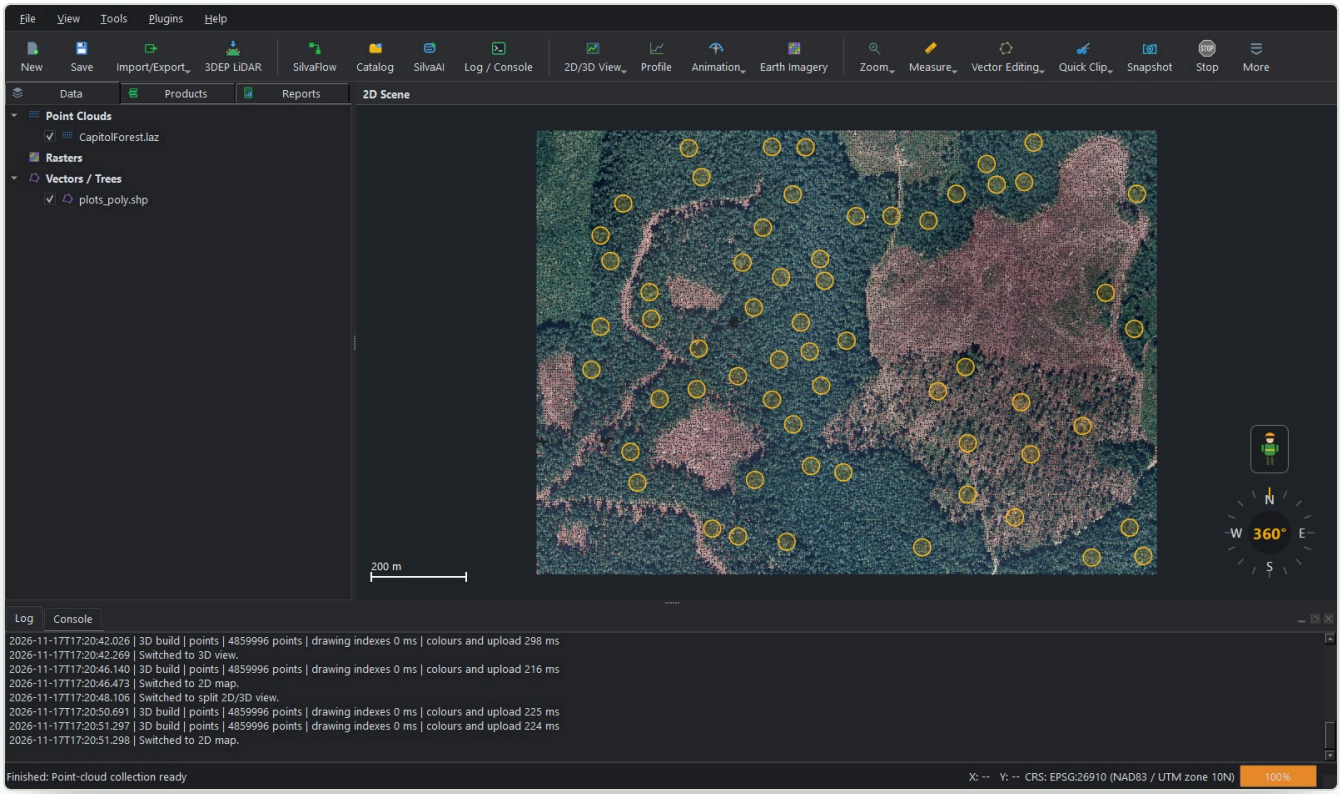


Figure 4.3 The 60 plots (plots_poly.shp) over the point cloud.



Figure 4.4 A plot area seen in 3D: the trees a plot clip will hold.

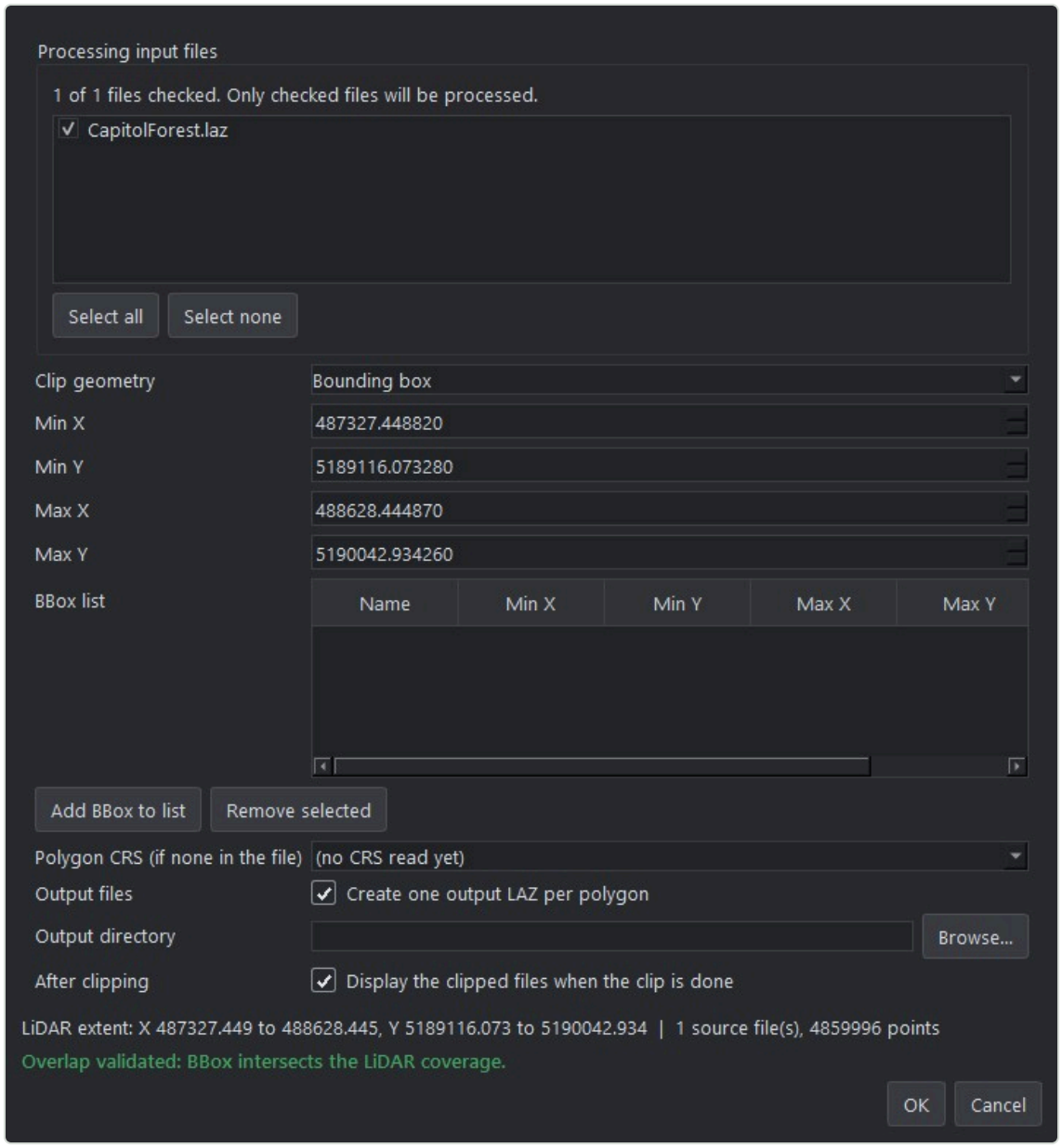


Figure 4.5 Clip Point Cloud.

Result You can cut out any area or plot from the cloud and keep it as a LAZ file.

Did you know? A Quick Clip is a selection of the points already loaded: nothing is copied or changed until you save it.

Check your understanding

1. What is the difference between Clip IN and Clip OUT?
2. Why cut plot clips from the normalized cloud when you want plot metrics?

05 EXERCISE 5

From ground to terrain products

SilvaLiDAR Air 0.1.8.80

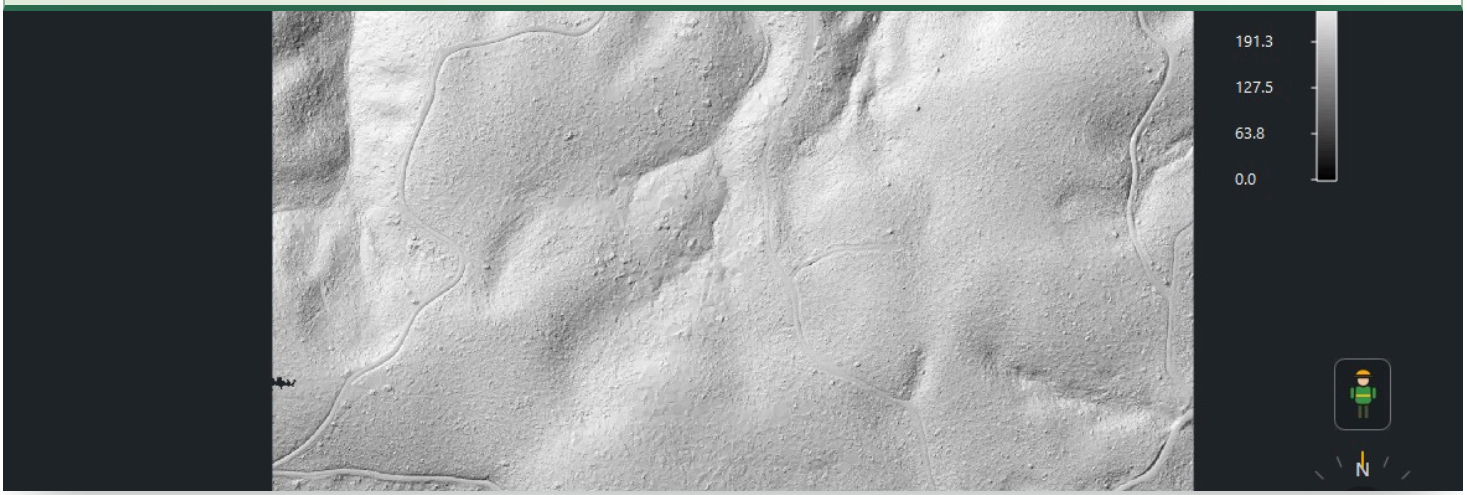


Figure 5.1 What you will make in this exercise.

Introduction

In this exercise you flag noise points, classify the ground, build a digital terrain model (DTM), and derive hillshade, slope, aspect and contours from it.

You will learn to

- ✓ Classify ground returns
- ✓ Build a digital terrain model
- ✓ Derive hillshade, slope, aspect and contours
- ✓ Run the same chain from the command line

Prerequisites

- Exercise 2

Overview of major steps

1. Remove noise, choosing the search radius
2. Classify the ground
3. Build the DTM
4. Make terrain products
5. Do the same from the command line

Procedure

Part 1: Noise removal and the search radius (optional)

1. *Open* **Tools** › **Point Cloud** › **Noise Removal**. Keep **Classify isolated points using 3D neighborhood** ticked.
2. A point is noise when it has fewer than **Minimum neighbors** (2) other points within the **Search radius**. *Keep* the default **5 m** for a first run and *Click* **OK**: noise points become class 7.
3. *Colour* the cloud by **Classification** and *look* at the stand from the side: the noise points stand out in their own colour.
4. *Compare* other radii: *reopen* the point cloud before each run, because points already in class 7 stay class 7, then run the tool again with another **Search radius**.

5. A small radius flags more points; on sparse data it marks real canopy and understory returns as noise. A large radius keeps only the really isolated returns. *Choose* the radius that flags only the points you see as noise in your data.

Search radius	Points flagged as noise	Share of the cloud
1 m	993,163	20.4 %
2 m	101,078	2.1 %
3 m	26,452	0.54 %
5 (default) m	3,777	0.08 %
8 m	245	0.005 %

Note There is no single right radius: it depends on the point density and on what you count as noise. Try a few values on your data and keep the one you trust.

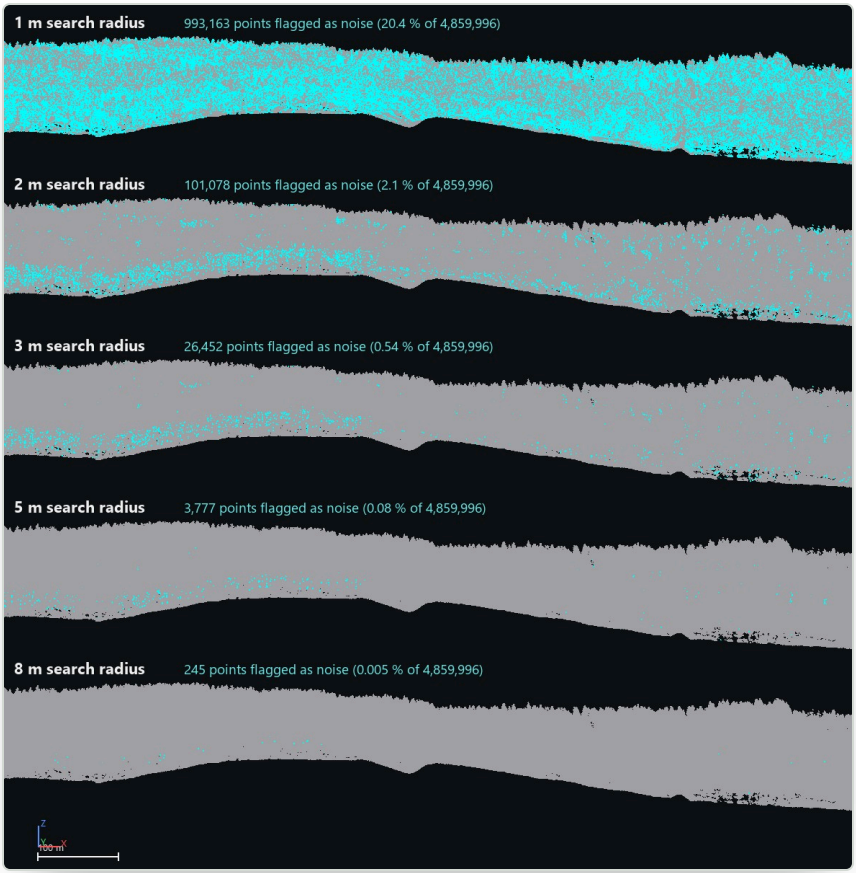


Figure 5.2 The same side view of the stand after Noise Removal with search radii of 1, 2, 3, 5 and 8 m (2 neighbours): noise points in cyan.

Part 2: Ground filtering

1. *Open* **Tools** › **Terrain** › **Ground Filtering**.
2. *Keep* **PTD - Progressive TIN Densification** and its settings and *Click* **OK**.
3. *Colour* the cloud by **Classification**: ground returns are class 2.

Tip Ground is searched among the last and single returns, which keeps low branches out of the ground.

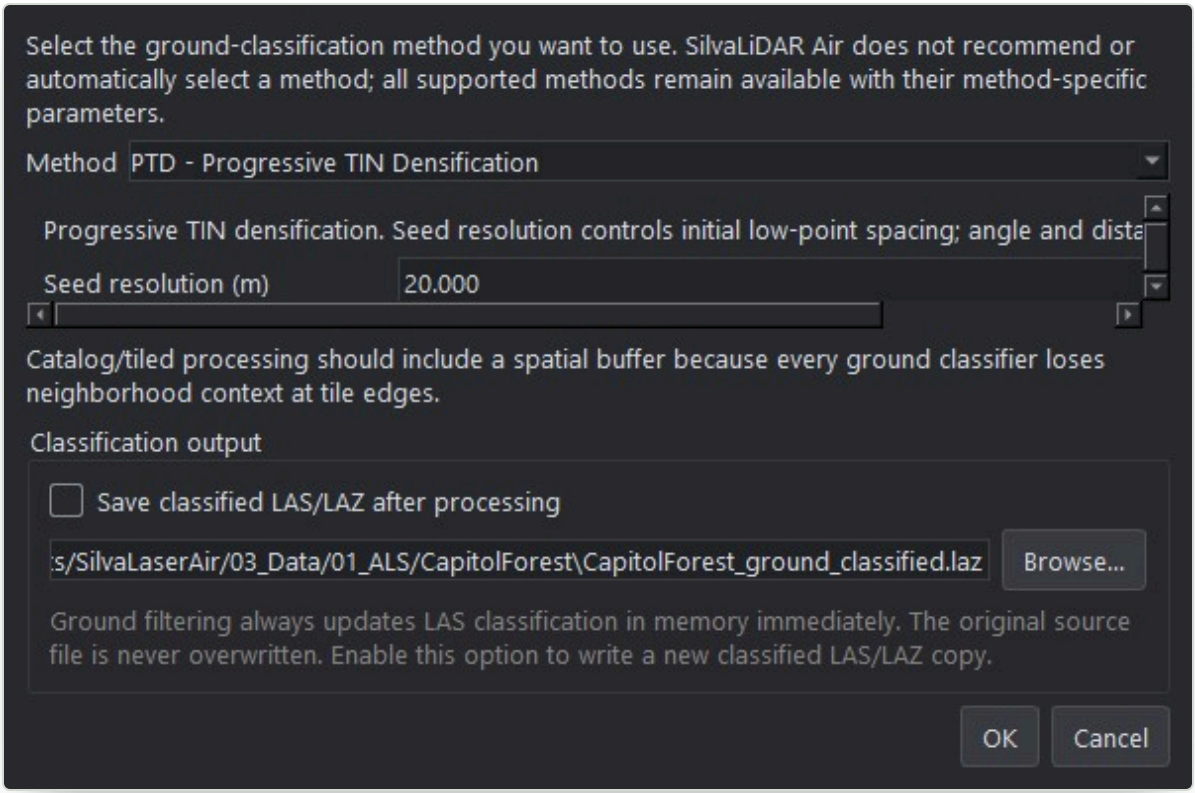


Figure 5.3 Ground Filtering.

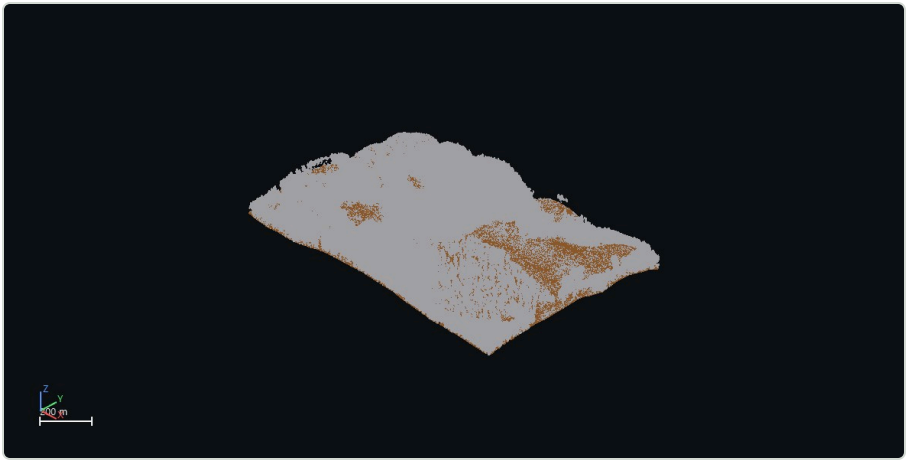


Figure 5.4 Ground and vegetation.

Part 3: The DTM

1. *Open* **Tools** › **Terrain** › **DTM**.
2. *Keep* **TIN** / **Delaunay** and **0.50 m**, and *Click* **OK**.
3. The **DTM** is added under **Rasters**. *Untick* the point cloud to see it on the map, and in 3D.

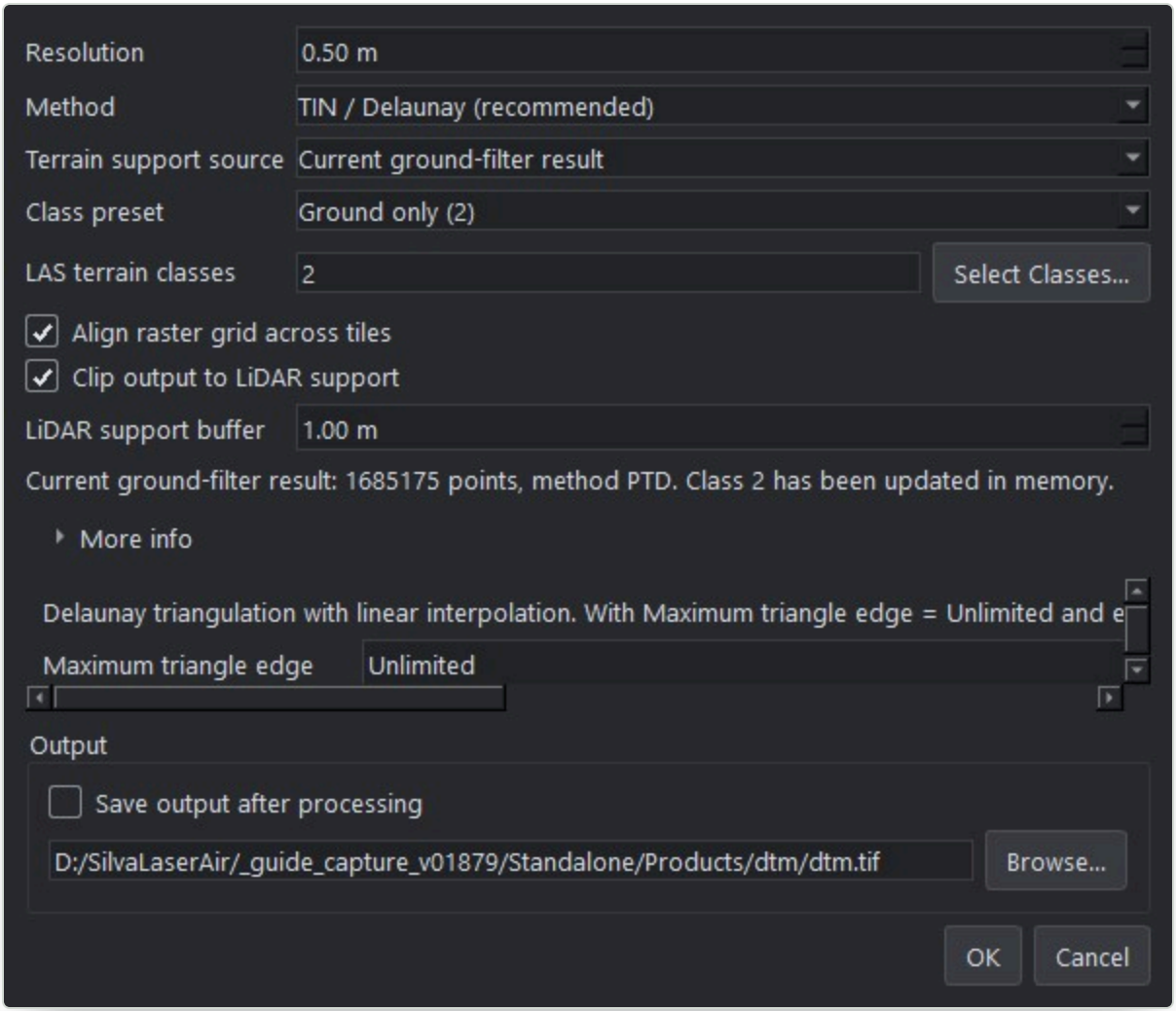


Figure 5.5 The DTM window.

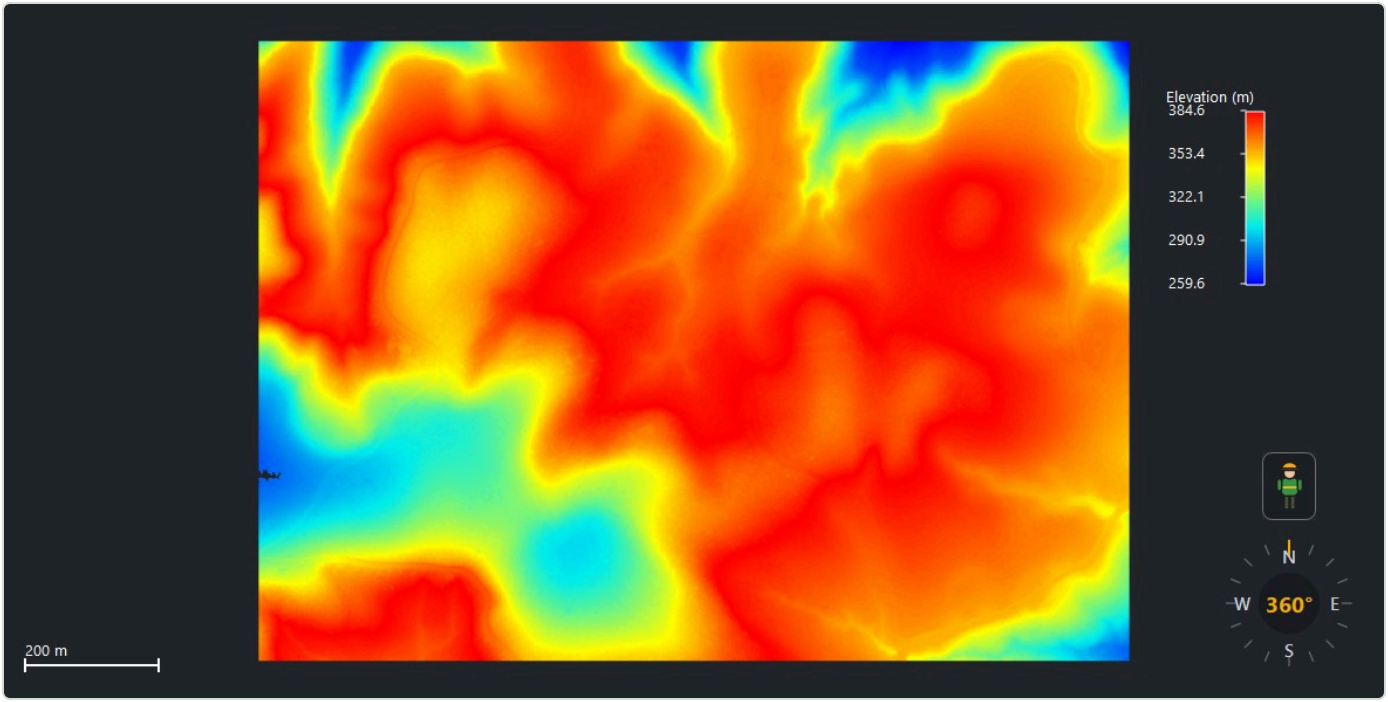


Figure 5.6 The DTM.

Part 4: Terrain products

1. *Run* **Tools** › **Terrain** › **Terrain Analysis** › **Hillshade**, then **Slope**, **Aspect** and **Contours**.
2. *Look* at the hillshade: roads, skid trails and old harvest boundaries stand out.
3. *Show* one product at a time with the checkboxes.

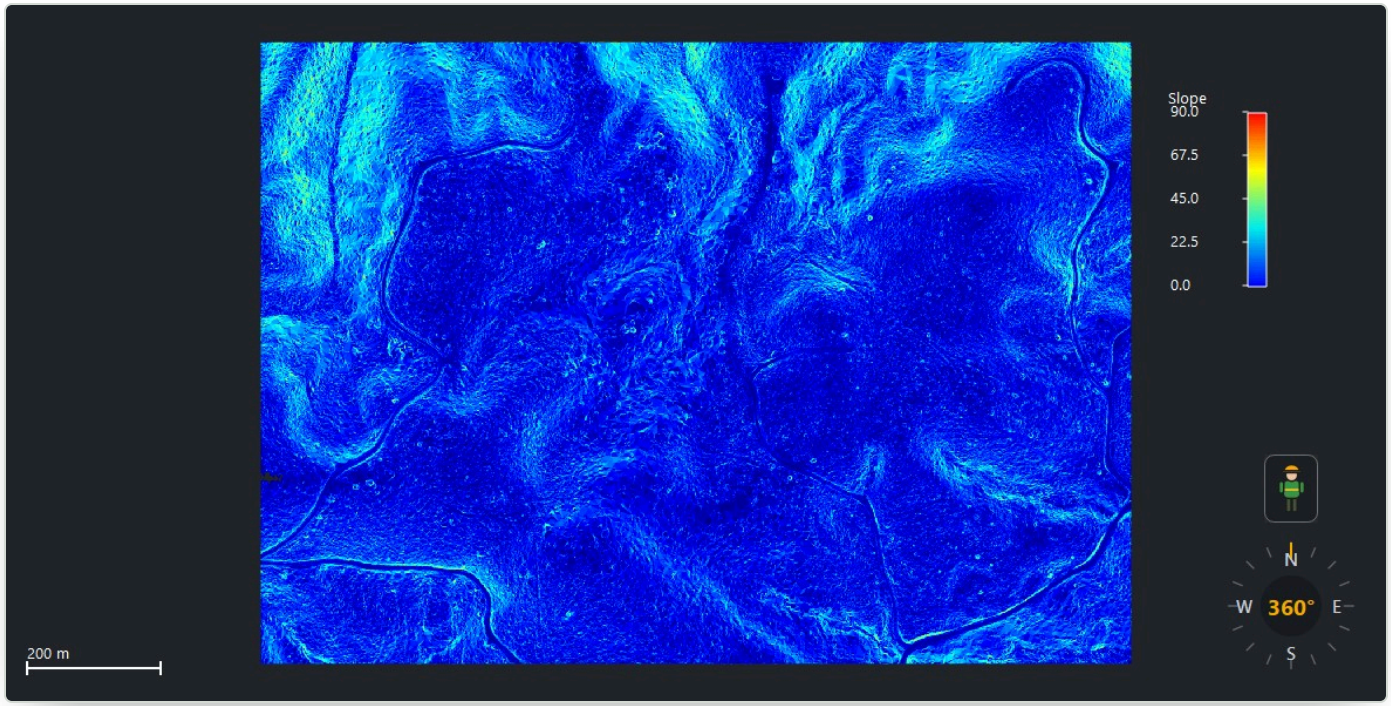


Figure 5.7 Slope.



Figure 5.8 Contours.

Part 5: The same from the command line

1. *Open* a Command Prompt in the SilvaLiDAR Air program folder and *run*:

Command line

```
SilvaLiDARAirCLI.exe --tool ground --input C:\SilvaLiDARAirExercise\01_Sites\01_CapitolStateForestWA\01_LAZ\CapitolForest.laz --output C:\SilvaLiDARAirExercise\03_Projects\cli_out\ground.laz --method ptd
```

Command line

```
SilvaLiDARAirCLI.exe --tool dtm --input C:\SilvaLiDARAirExercise\03_Projects\cli_out\ground.laz --output C:\SilvaLiDARAirExercise\03_Projects\cli_out\dtm.tif --resolution 1
```

Command line

```
SilvaLiDARAirCLI.exe --tool hillshade --input C:\SilvaLiDARAirExercise\03_Projects\cli_out\dtm.tif --output C:\SilvaLiDARAirExercise\03_Projects\cli_out\hillshade.tif
```

Tip `SilvaLiDARAirCLI.exe --tool dtm --help` lists every option of a tool.

Result You have a classified cloud, a DTM and its terrain products, made in the window and from the command line.

Did you know? DTM cells lie on whole multiples of the cell size in map coordinates, so the DTM lines up with the CHM and with rasters from other software.

Check your understanding

1. Where on the hillshade can you see roads or skid trails?
2. Why is the ground searched only among last and single returns?
3. When would you choose a 1 m DTM instead of 0.5 m?

06 EXERCISE 6

CANOPY HEIGHT AND CANOPY GAPS

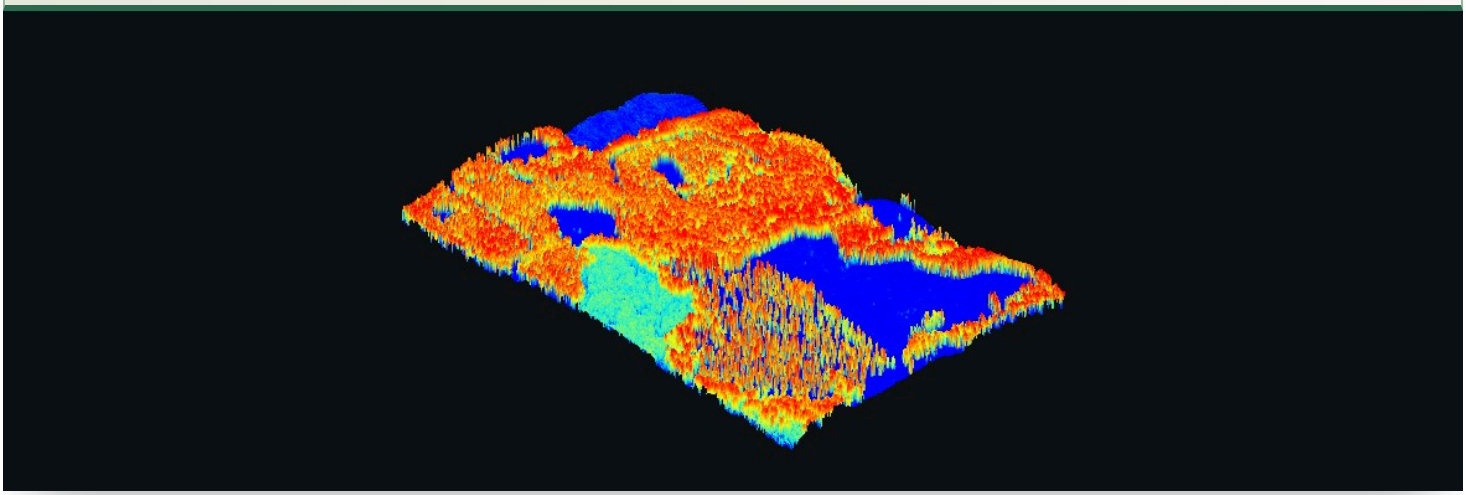


Figure 6.1 What you will make in this exercise.

Introduction

In this exercise you turn elevations into heights above ground, build the canopy height model (CHM) and find the canopy gaps.

You will learn to

- ✓ Normalize heights above ground
- ✓ Build a canopy height model
- ✓ Map the canopy gaps

Prerequisites

- Exercise 5 (ground filtering done)

Overview of major steps

1. Normalize the heights
2. Build the CHM
3. Find the canopy gaps

Procedure

Part 1: Height normalization

1. *Open* **Tools** › **Terrain** › **Height Normalization**, keep **Direct TIN** and *Click* **OK**.
2. In 3D the terrain is now flat: each point's height is its height above the ground.

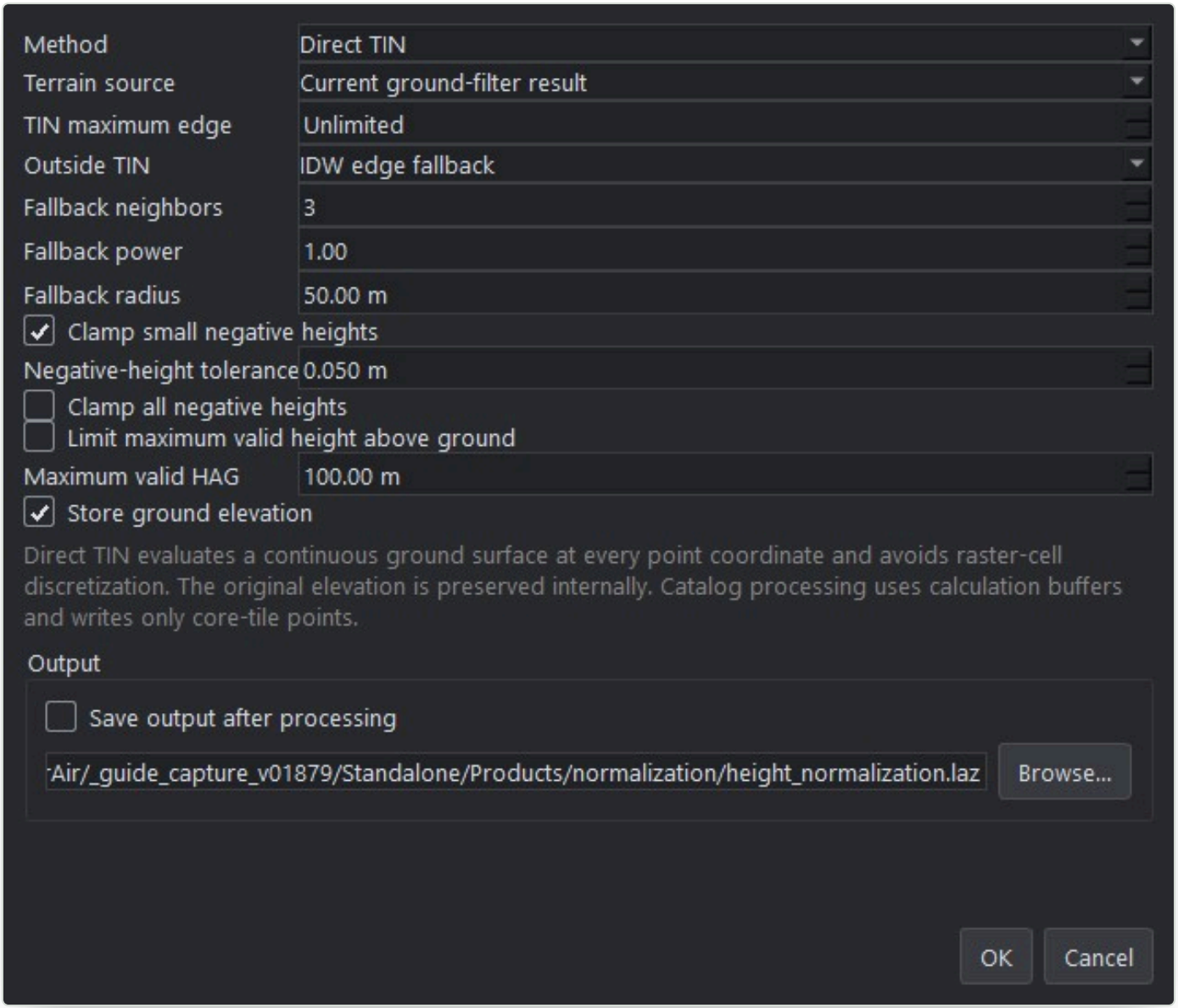


Figure 6.2 Height Normalization.

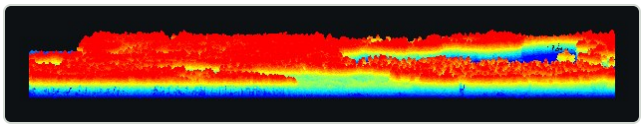


Figure 6.3 After height normalization the ground is flat at 0 m.

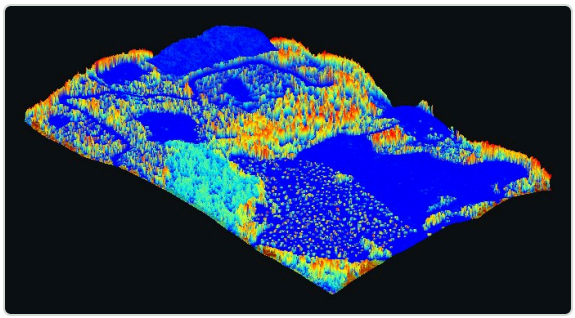


Figure 6.4 The CHM draped in 3D.

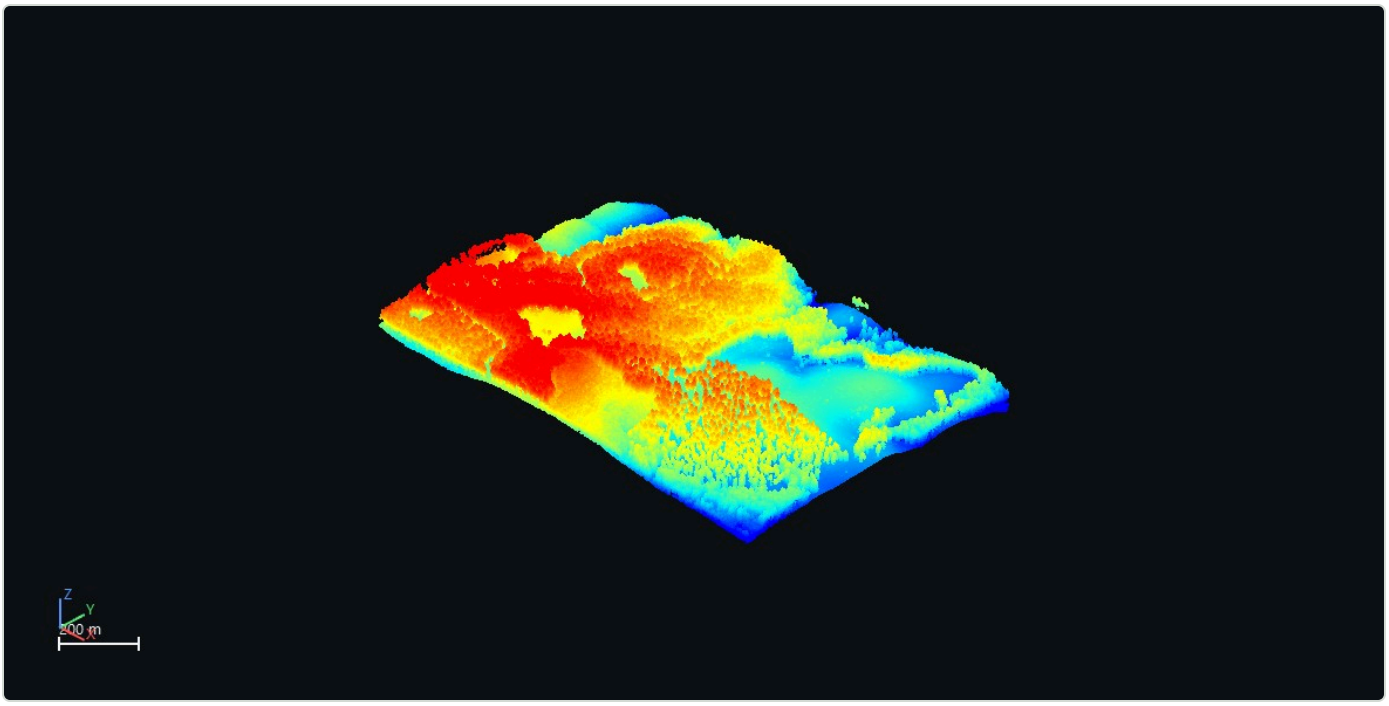


Figure 6.5 The normalized cloud.

Part 2: The CHM

1. *Open* **Tools** › **Canopy** › **CHM**.
2. *Keep* **P2R maximum** at **1.000 m**, or *choose* **Pit-free** at **0.5 m** for a smoother canopy. *Click* **OK**.
3. *Look* at the CHM on the map and in 3D.

> **Tip** Pit-free avoids the small false pits P2R leaves where a crown has no return in a cell.

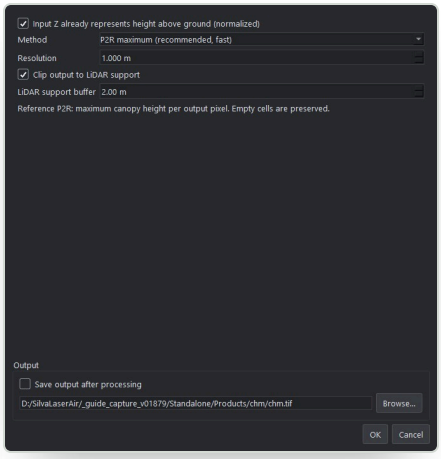


Figure 6.6 The CHM window.

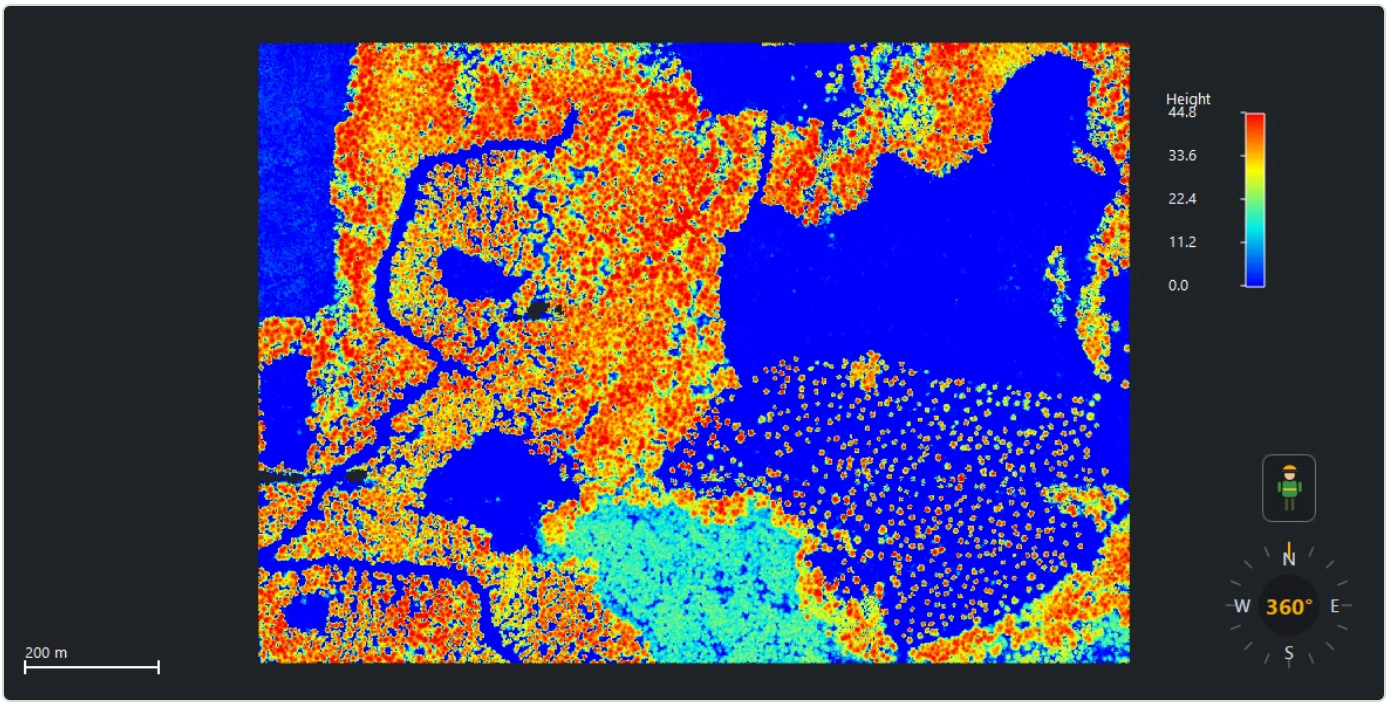


Figure 6.7 The CHM.

Part 3: Canopy gaps

1. *Open* **Tools** › **Canopy** › **Canopy Gap**.
2. *Keep* a **gap height threshold** of **10 m** and areas of **1** to **10,000 m²**; *Click* **OK**.
3. Each gap gets its own colour; the per-gap statistics are written next to the gap raster.

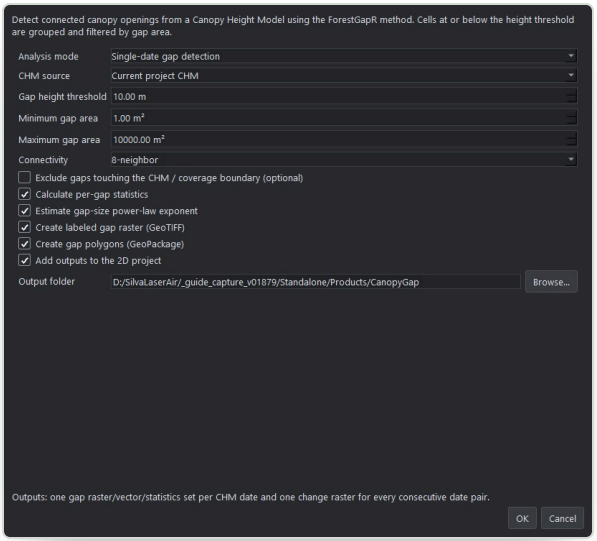


Figure 6.8 Canopy Gap.

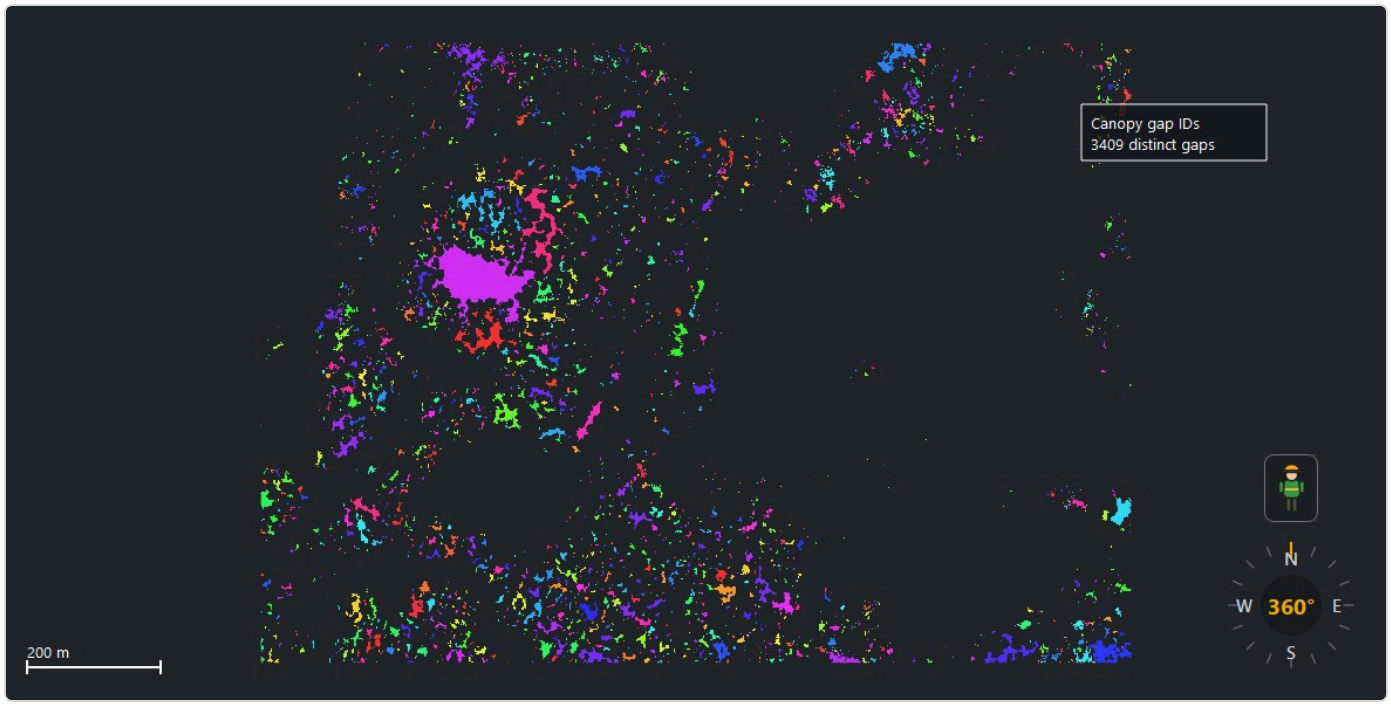


Figure 6.9 The canopy gaps.

Result You have normalized heights, a canopy height model and a map of the canopy gaps.

Did you know? The canopy-gap defaults (10 m height, 1 to 10,000 m^2) are those of the ForestGapR method.

Check your understanding

1. How does the CHM change between P2R maximum and pit-free?
2. Which parts of the stand have the most gaps, and why?

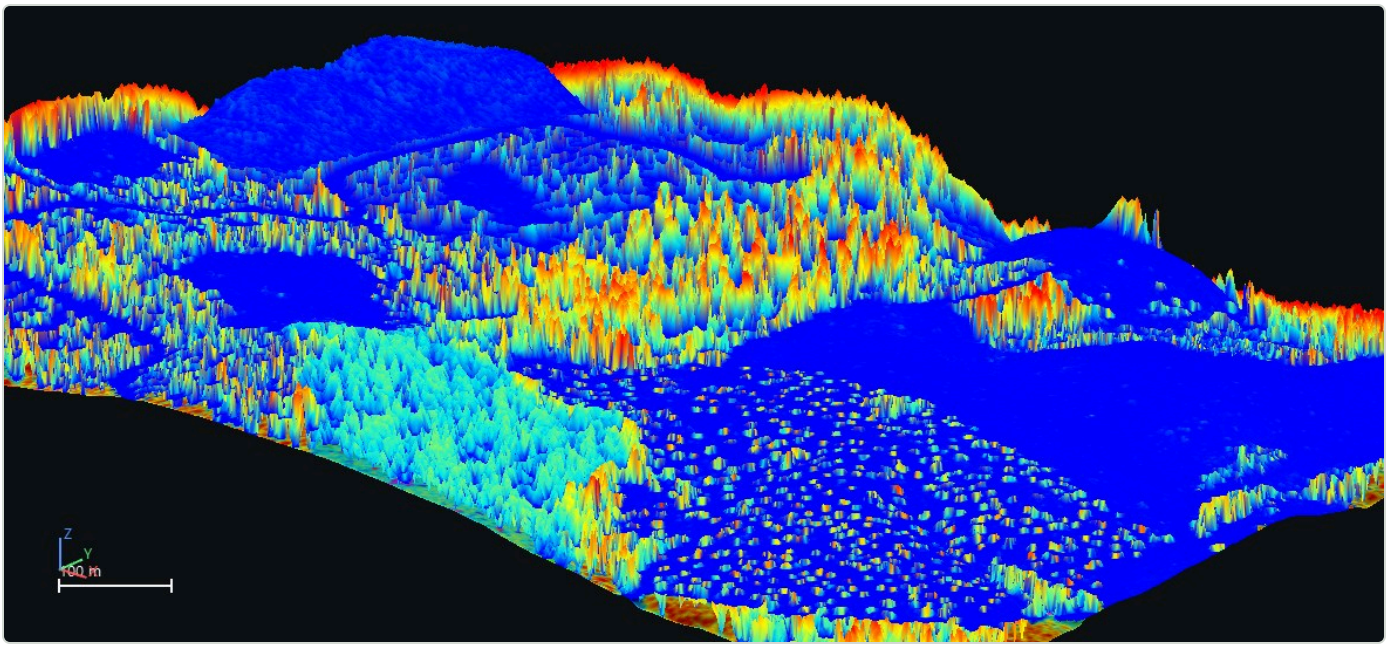


Figure 6.10 The CHM close up: each bump is a crown.

07 EXERCISE 7

INDIVIDUAL TREES, THE VIRTUAL FOREST AND THE FORESTER

SilvaLiDAR Air 0.1.8.80

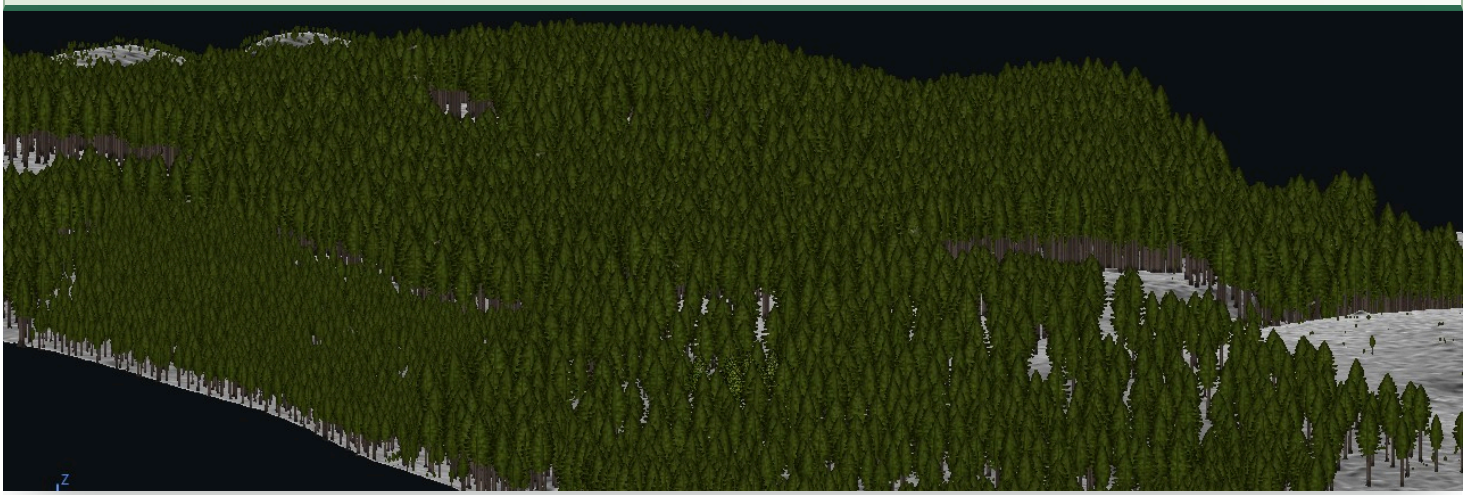


Figure 7.1 What you will make in this exercise.

Introduction

In this exercise you detect every tree, measure them, place a 3D model on each, and walk through the result.

You will learn to

- ✓ Detect individual trees
- ✓ Compute per-tree metrics
- ✓ Build a realistic virtual forest from a 3D model
- ✓ Walk, ride and fell trees with the forester and his dog
- ✓ Export the forest to Blender or Unity

Prerequisites

- Exercise 6 (normalized heights and CHM)

Overview of major steps

1. Detect the trees
2. Measure the trees
3. Create the virtual forest
4. Select a tree and read its attributes
5. Walk with the forester
6. Select a tree under the canopy
7. Ride, bring the dog and fell a tree
8. Export the forest for Blender or Unity

Procedure

Part 1: Tree detection

1. *Open* **Tools** › **Canopy** › **Individual Tree Detection & Extraction**.
2. *Keep* **Silva et al. 2016** and *Click* **OK**.
3. *Colour* the cloud by **Tree ID**: each tree has its own colour. **Tree Tops** and **Crown Boundaries** are added as layers.

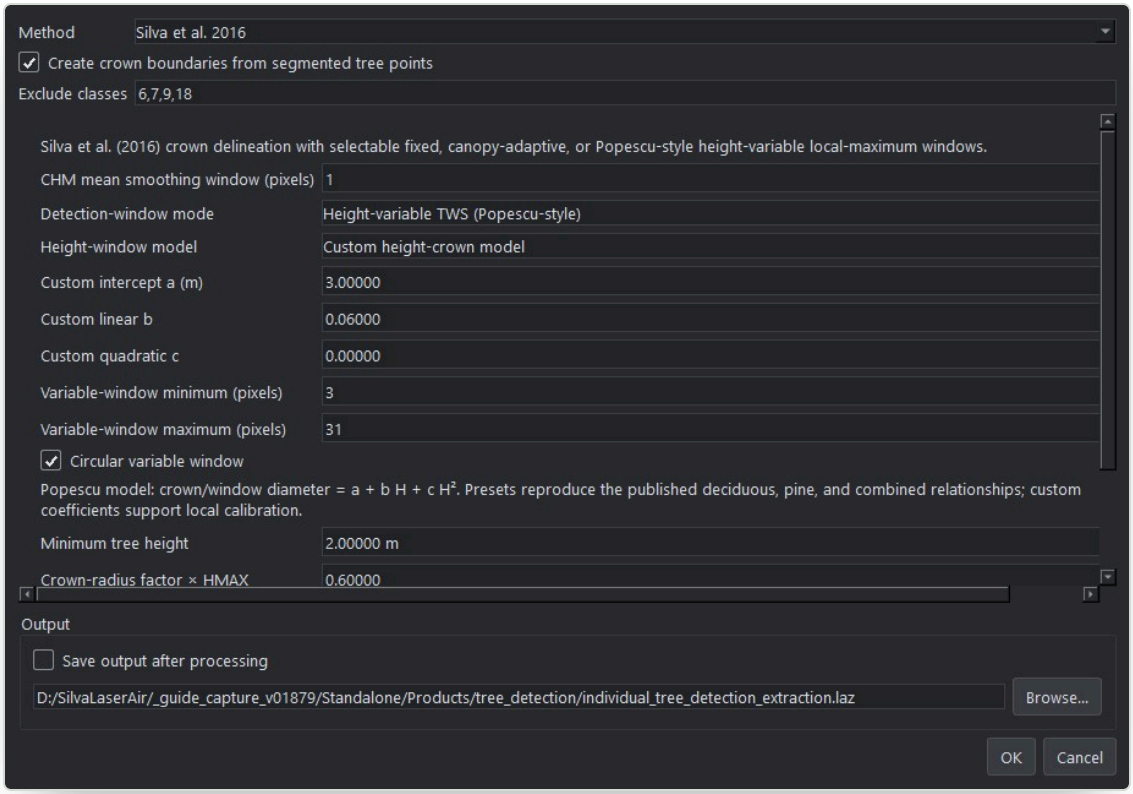


Figure 7.2 Tree detection.

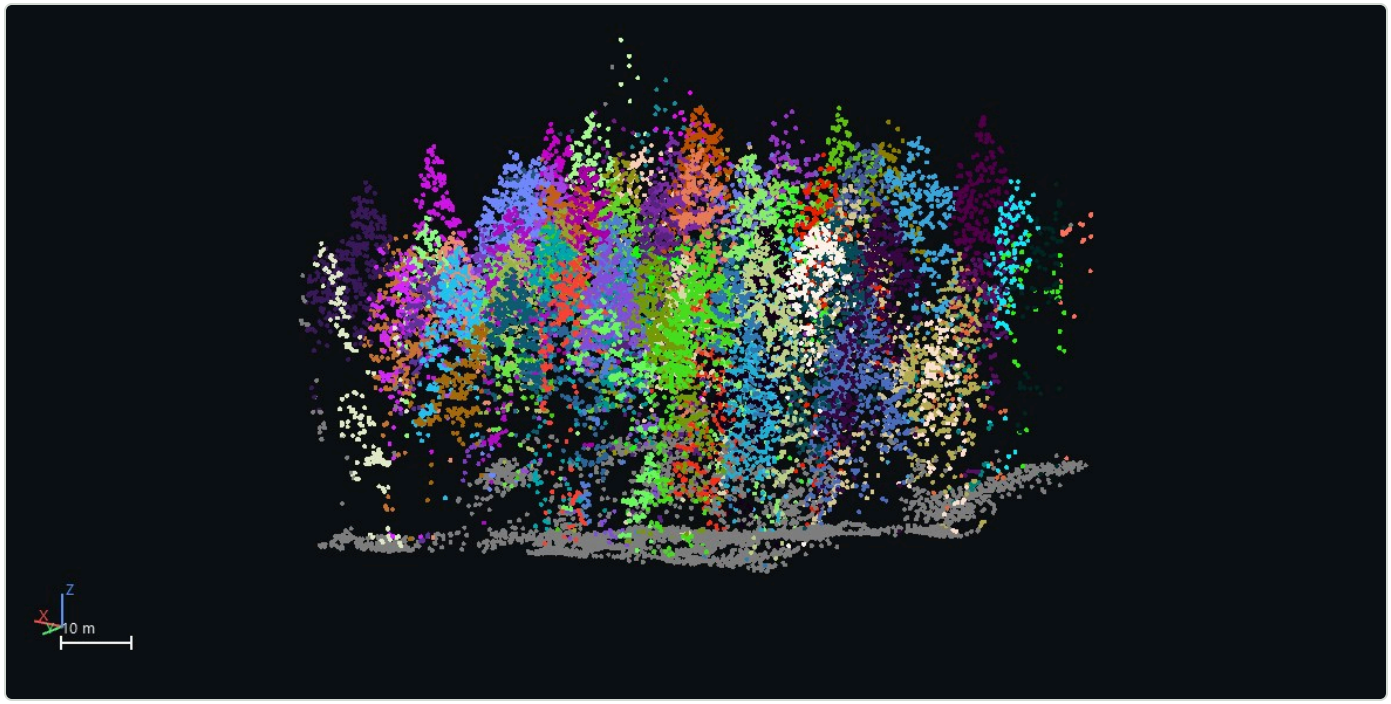


Figure 7.3 Each tree in its own colour, close up.

Part 2: Tree metrics

1. *Open* **Tools › Metrics › Individual Tree Metrics**, *choose* **Balanced**, *tick* **Save output**, *Click* **OK**.

2. **individual_tree_metrics.csv** lists every tree: position, height, crown radius and crown base height; the full table has every metric.

> **Note** Crown volume is a crown-envelope volume, not wood volume or biomass.

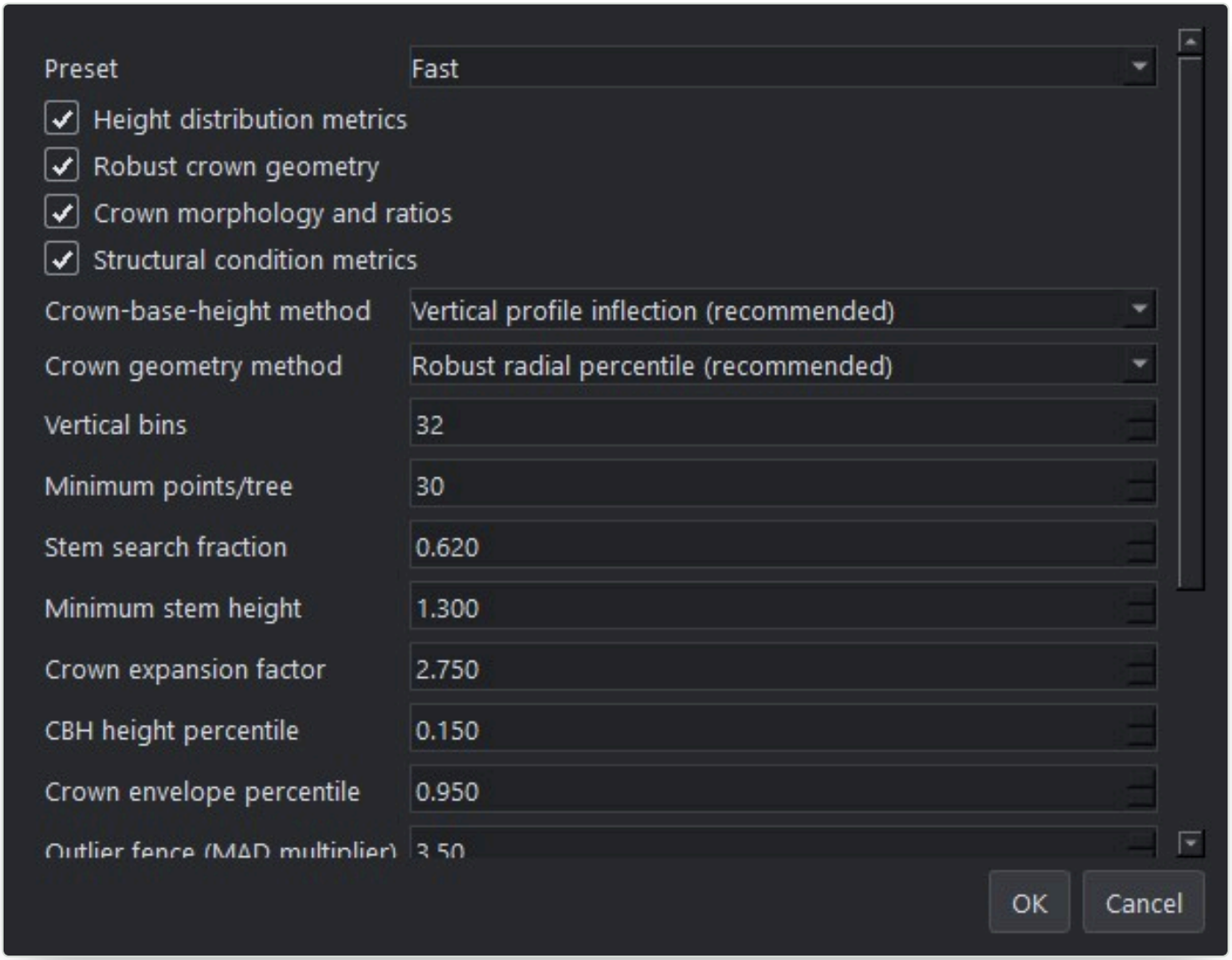


Figure 7.4 Individual Tree Metrics.

Part 3: The virtual forest

1. *Open* **Tools** › **Virtual Forest** › **Create Virtual Forest**. The **Tree List** shows every detected tree with its height and crown.
2. For a quick look, keep **Rendering family** on **Simple geometric trees** and *Click* **OK**.
3. For a realistic forest, *open* the window again, *set* **Rendering family** to **Realistic 3D models**, *Click* **Import 3D model files…** and *select* a tree model, for example **fir_douglas_pine.glb** (GLB, glTF, OBJ, FBX and other formats are accepted).
4. *Tick* **Include automatically placed moving birds** if you like, and *Click* **OK**. The model is planted on every detected tree, scaled to its height and crown, standing on the terrain.
5. *Untick* the point cloud to see the forest alone; *tick* the Hillshade raster to drape it as the ground.

Tip Thousands of model trees stay smooth to orbit and walk: each tree is drawn as the full model, a lighter mesh or a picture, depending on its size on screen.

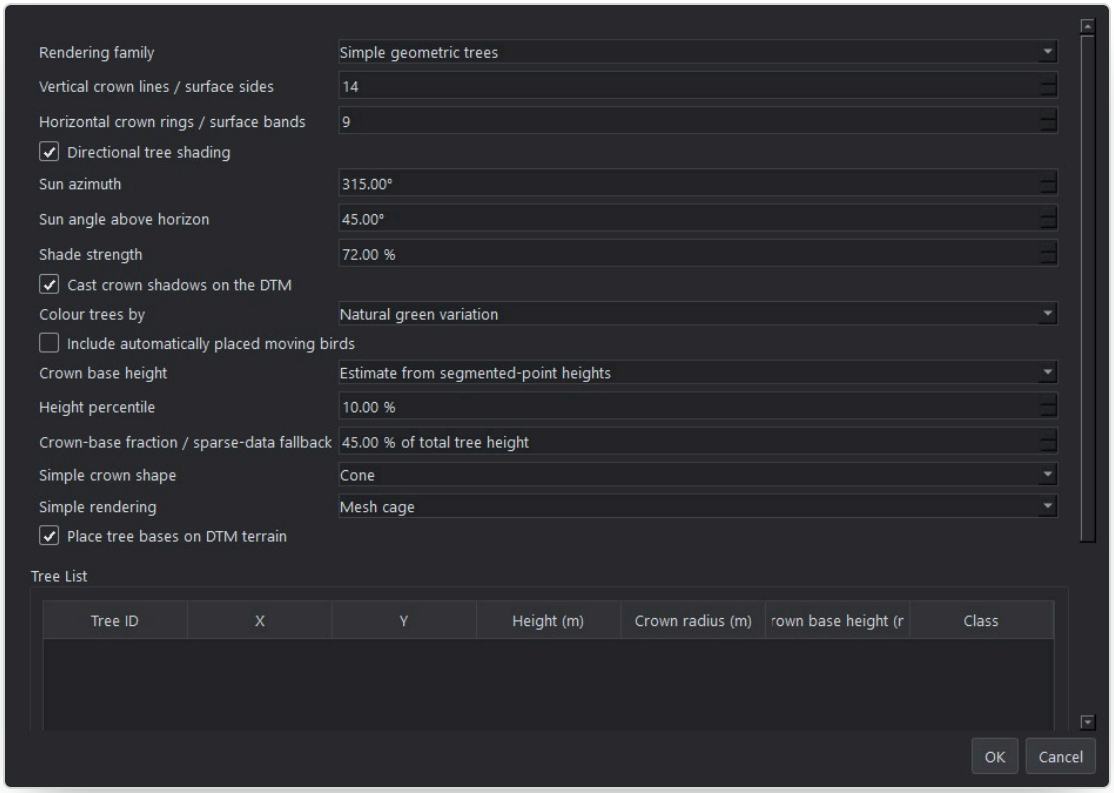


Figure 7.5 Create Virtual Forest: rendering family and tree list.

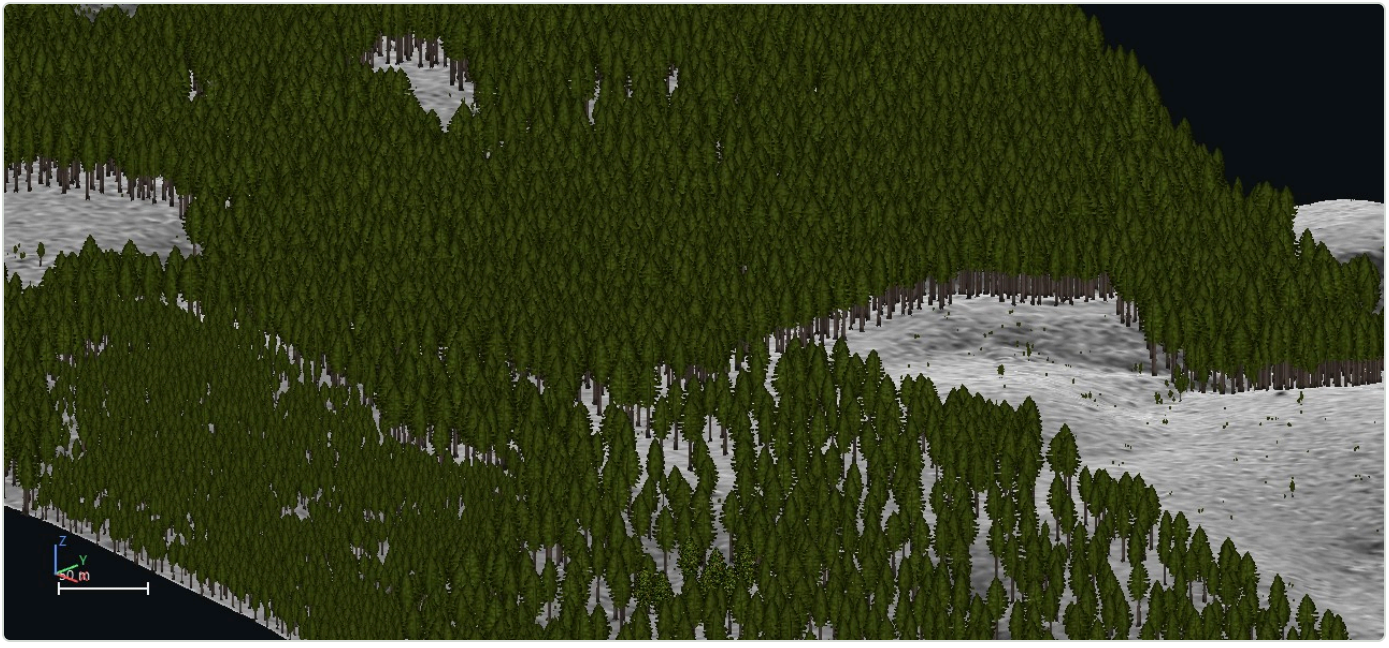


Figure 7.6 Realistic 3D models: the “Fir Douglas Pine” model (High Quality Work, Sketchfab) on all 16,054 detected trees, on the hillshade.

Part 4: Select a tree

1. *Zoom* in on the virtual forest and *click* a tree. The tree turns yellow and its **attribute card** opens beside the pointer.
2. The card shows what was measured from the LiDAR points for that tree: **height**, **crown radius**, **width**, **area**, **crown base height**, **crown length**, its **condition** and its coordinates.
3. *Click* another tree to compare, or *click* the ground (or the × of the card) to clear the selection.
4. The same click works under the canopy while you walk with the forester (Part 6).

> **Note** The card shows only values measured from the points. A tree placed by hand from a 3D model, with no LiDAR tree behind it, says so.



Figure 7.7 A selected tree and its attribute card.



Figure 7.8 The model trees among the LiDAR points.

Part 5: Walk with the forester

1. *Show* the 2D map and *drag* the **forester** button onto the map: the 3D scene starts a walk at that spot.
2. *Walk* with `W` `A` `S` `D` or the arrow keys; `Shift` runs, `Space` jumps, *drag* to look around.
3. *Use* the Walk menu in the 3D scene to switch between third and first person.
4. *Click* the Walk button on the left edge of the 3D scene to stop walking.



Figure 7.9 Drag the forester onto the map.

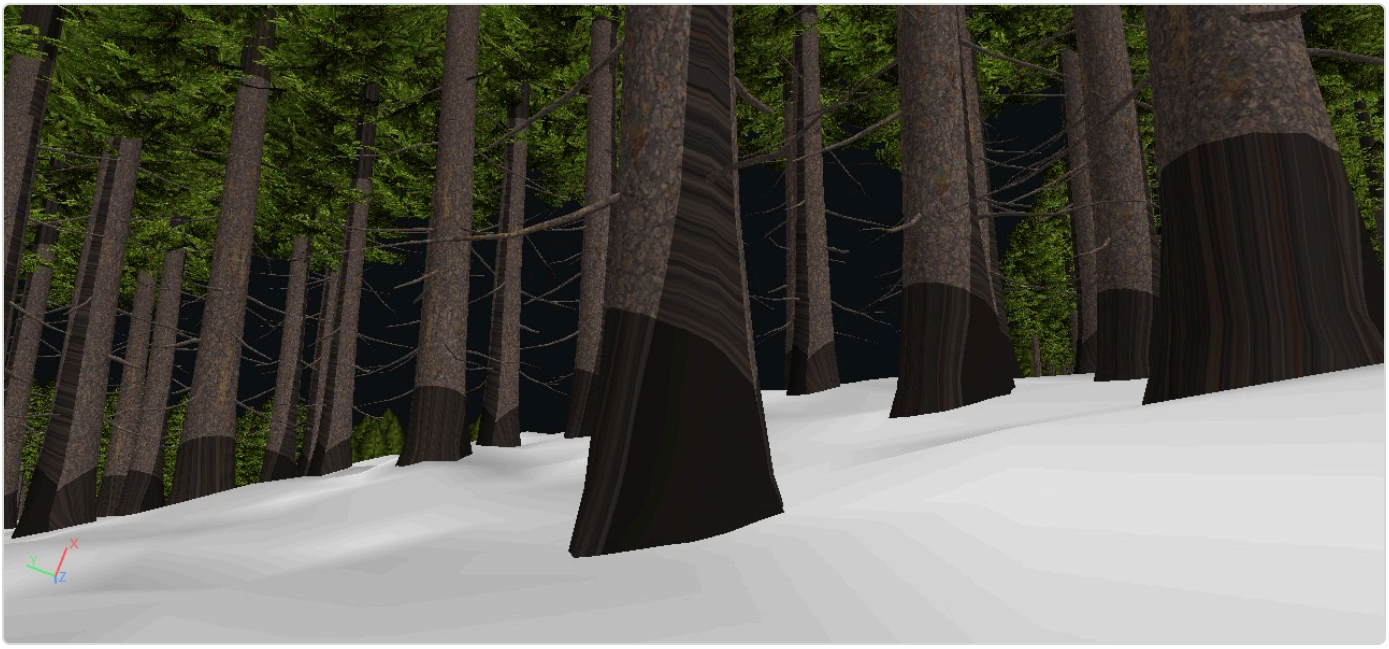


Figure 7.10 First person under the canopy: the trunks rise into the crowns overhead.

Part 6: Select a tree under the canopy

1. While walking, *stop* near a tree and *drag* to look up: in first person you stand among the trunks, under the crowns.
2. *Click* the stem of the tree. It turns yellow and its **attribute card** opens beside the pointer, with the same values as from above: height, crown radius, width, area, crown base height, crown length, condition and coordinates.
3. In third person the forester stays in the picture while you select trees around him.
4. *Click* another stem to compare, or the × of the card to clear the selection, and walk on.

> **Tip** Look up first: from under the crowns the trunk you aim at is the nearest one, so the click picks that tree and not one behind it.

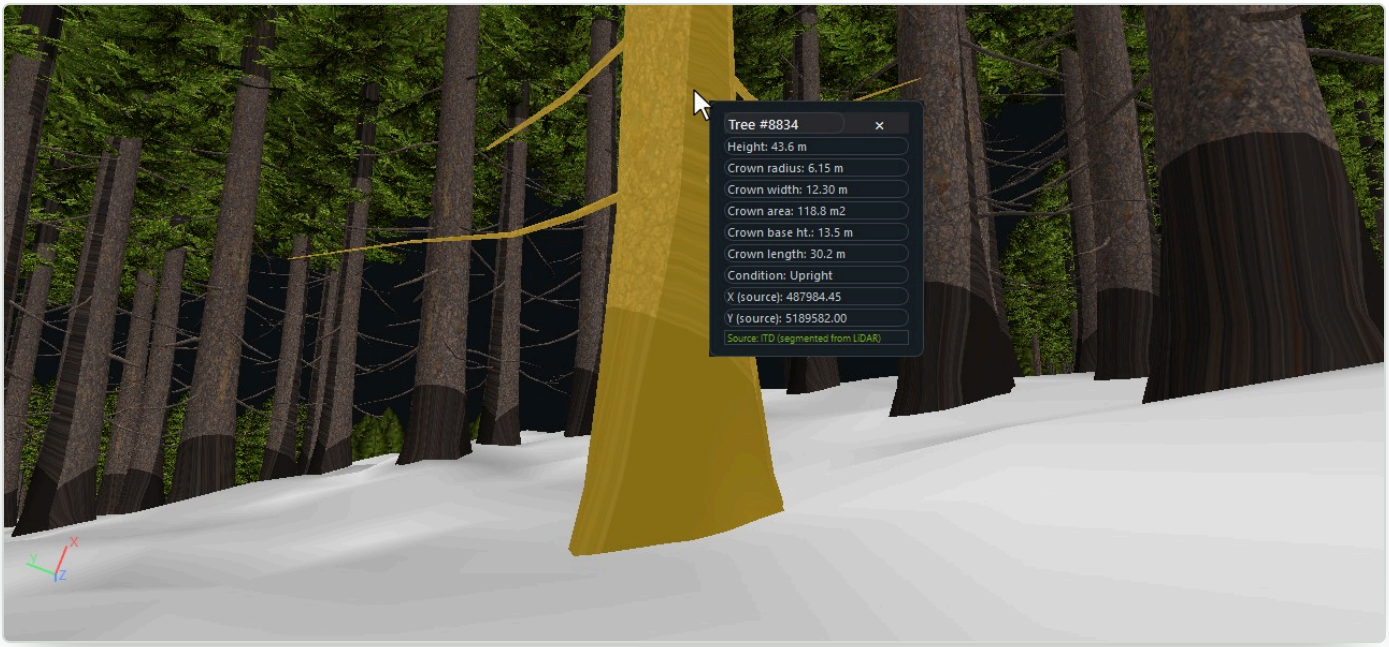


Figure 7.11 Under the canopy, first person: a click on the stem marks the tree in yellow and opens its attribute card.



Figure 7.12 The same in third person: the forester among the trunks, beside the tree he selected.

Part 7: Ride, bring the dog and fell a tree

1. While walking, *right-click* the 3D scene and open **Walk mode**. Under **Ride**, *choose* **Bicycle**, **ATV (four wheels)** or **Motorcycle**: the forester rides with his feet on the pedals, footrests or pegs and his hands on the grips. `Shift` goes faster.
2. Under **Dog**, *choose* **Bring the dog** and a breed: **Husky**, **Golden retriever** or **Dachshund**. The dog follows you; when you stop, it sniffs about and then sits beside you. *Press* `G` to bring the dog (or send it home) and `T` to throw a treat: the forester throws it overarm, the dog runs to it, eats it and comes back.
3. *Click* a tree so it is highlighted and *press* `C`: the forester walks to it by himself, steps up to the trunk and saws; the tree falls away from him and stays on the ground, with a stump about 30 cm high.
4. Felling changes the 3D virtual forest only: the point cloud, the tree table and the products keep the tree standing. **Restore cut trees** stands every felled tree up again.
5. Under **Forester**, *choose* who walks: man or woman, skin tone, round or almond eyes, face shape, hair colour and hairstyle, glasses and, for the man, a beard.

> **Tip** Felling changes nothing in your data: it is a way to look past a tree, or to show a thinning in a demonstration.



Figure 7.13 Riding the ATV through the stand, the dog on its rear rack (R brings it on).



Figure 7.14 The forester has stopped: the golden retriever sits beside him.



Figure 7.15 Felling a tree with the chainsaw: it falls away from the forester.

Part 8: Export the forest for Blender or Unity

1. With the forest created, *open* **File** › **Export 3D Scene (.glb)…**. The layers shown in the 3D Scene are ticked: *keep* **Virtual forest** (as created: your 3D models, or simple trees) and **Terrain** (plain or coloured with a raster), *tick* the point cloud or vector layers if you want them too, and *choose* a file name ending in **.glb**.
2. Each layer is its own group in the file, all in the same coordinates: your tree model is stored once and placed on each detected tree, with its textures, so the file stays small. The scene is turned Y-up, as Blender and Unity expect.
3. In **Blender**, *use* **File** › **Import** › **glTF 2.0**. In **Unity**, *add* the glTFast package (`com.unity.cloud.gltfast`) and *drag* the file into the project.
4. The scene is moved to a local origin near the data; that origin and the coordinate system are written beside the file in **<name>_origin.txt**, so the scene can be put back in place.

> **Note** Felled trees are left out of the export.

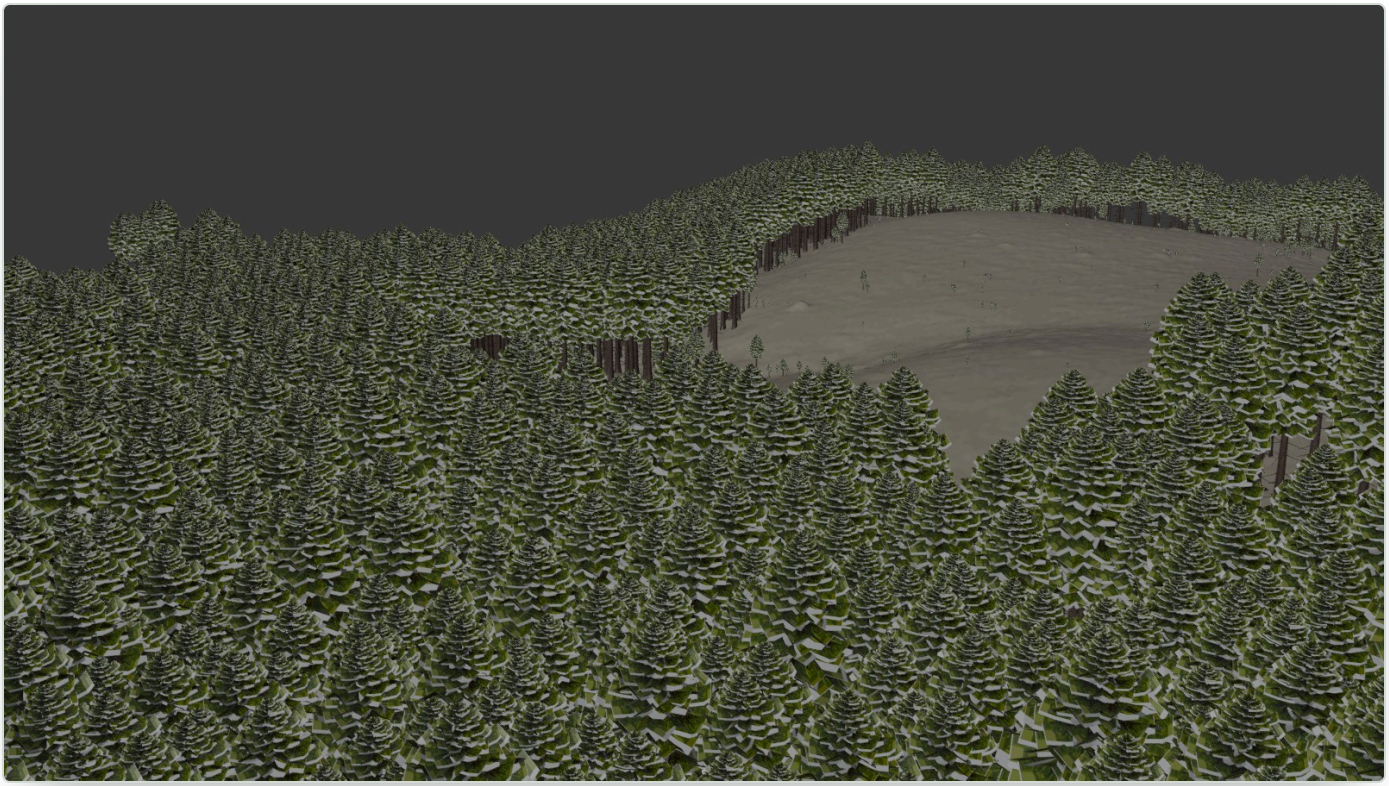


Figure 7.16 The exported virtual forest opened in Blender.

Result Every tree is detected, measured and drawn as a 3D model you can walk, ride and fell trees in, and export to Blender or Unity.

Did you know? On the example cloud the default settings find about 16,000 trees; each one gets its own 3D model, scaled to its height and crown.

Check your understanding

1. Why do two trees close together sometimes become one?
2. How would a smaller detection window change the number of trees?
3. Which tree attributes does the virtual forest use to size each model?



Figure 7.17 The felled tree on the ground, just before it disappears from the 3D forest.



Figure 7.18 Riding the mountain bike between the stems.

08 EXERCISE 8

PLOT AND GRID METRICS, AND YOUR OWN METRICS

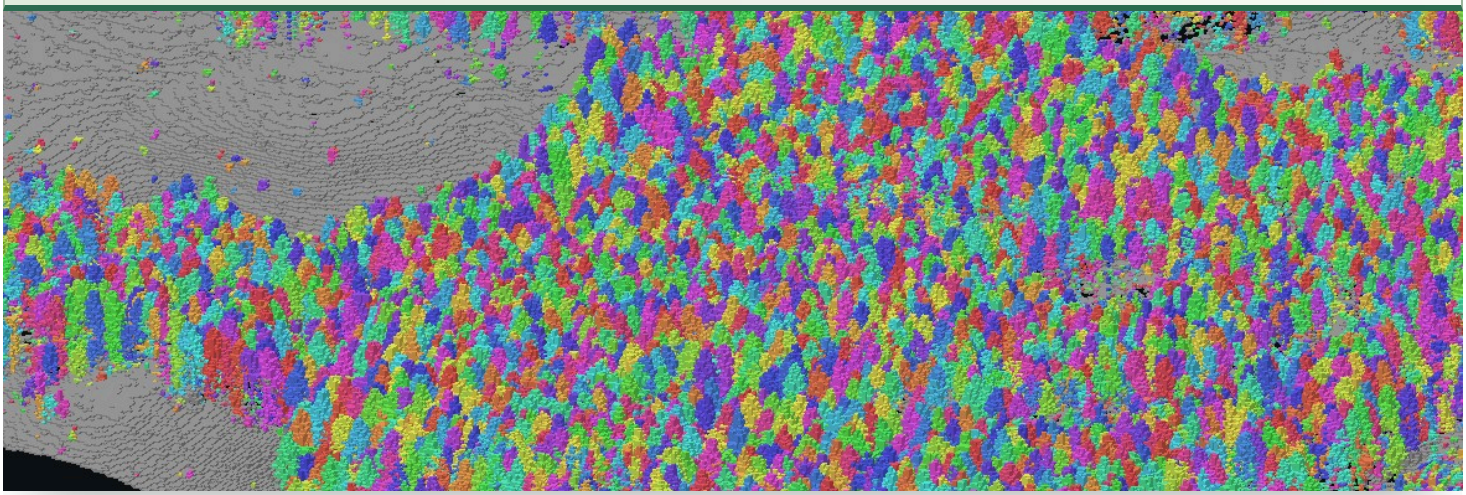


Figure 8.1 What you will make in this exercise.

Introduction

In this exercise you compute LiDAR metrics for the stand and for a 20 m grid, design your own metrics in the Custom Metric Designer, and map them.

You will learn to

- ✓ Compute metrics for plots
- ✓ Compute metrics for a grid over the area
- ✓ Describe vertical structure with voxels

Prerequisites

- Exercise 6 (heights above ground)
- For metrics per plot: the plots loaded (Exercise 4, Part 3)

Overview of major steps

1. Cloud metrics
2. Metrics of several files (plot clips)
3. Design metrics computed from the points
4. Build metrics from computed metrics
5. Grid metrics with your metrics, as maps
6. Voxel metrics

Procedure

Part 1: Cloud metrics

1. *Open* **Tools** › **Metrics** › **Cloud Metrics**. It measures the point cloud you give it: the whole stand here, one clip, or several files at once (Part 2).
2. *Keep* **Height above ground** and the **2 m** canopy threshold, *tick* **Save output after processing** and *Click* **OK**.
3. A summary opens and the CSV holds every metric: height percentiles (**p05** … **p99**), **zmean**, **zmax**, **canopy_cover_pct**, point density, return and class shares…

Note In SilvaFlow, Cloud Metrics measures what its connected box sends: after a **Clip** box with **plots_poly.shp**, one row per plot (Exercise 11). From the command line: `--tool cloud-metrics` (Exercise 14). These plots are random illustration plots, not field plots.

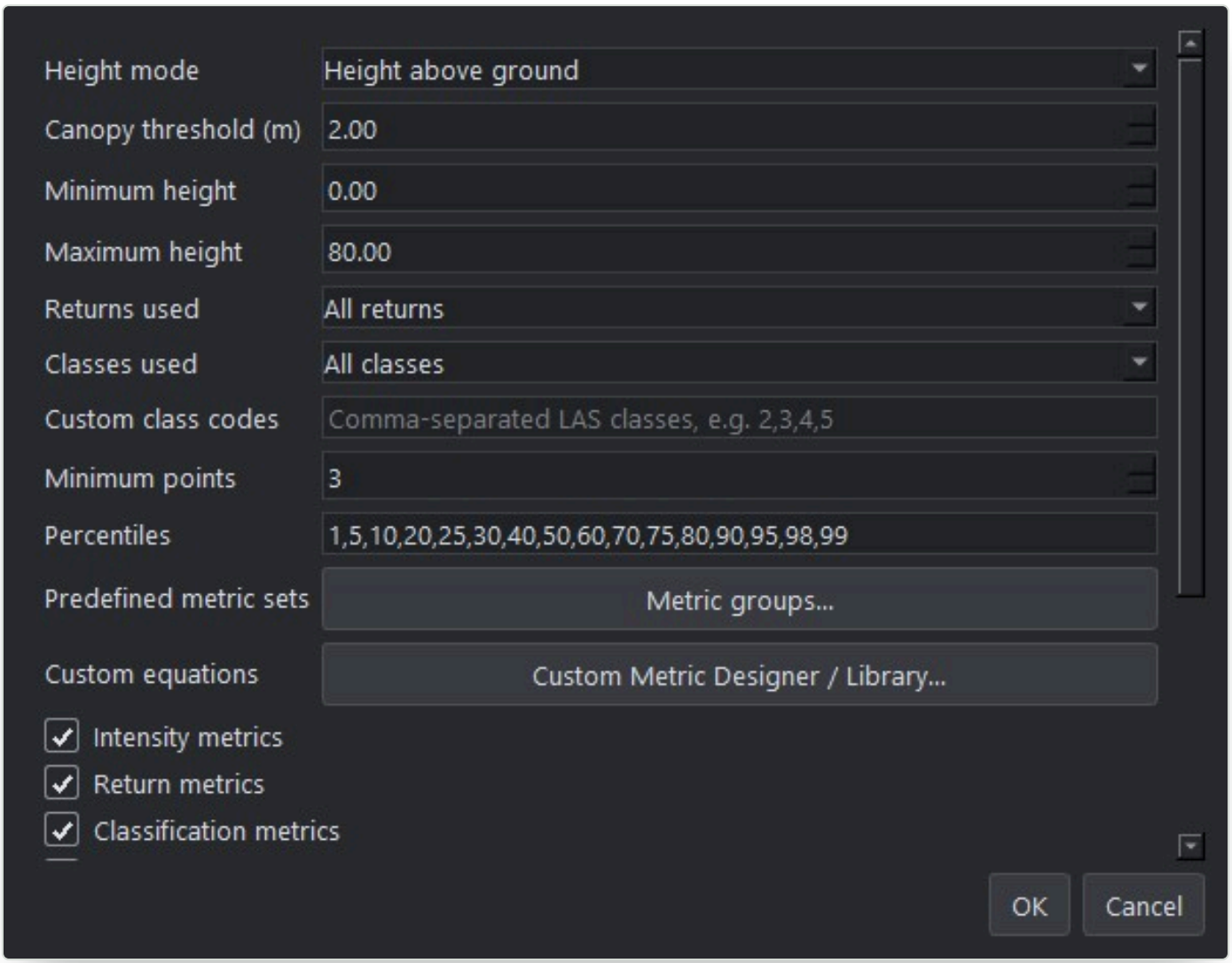


Figure 8.2 Cloud Metrics.

Part 2: Metrics of several files: plot clips

1. *Import* several files together, for example the plot clips **clip_1.laz** … **clip_12.laz** of Exercise 4 (Import… with several files selected). They open as one collection, each file a layer.
2. *Open* **Cloud Metrics**. The **Input** list at the top shows the files: *tick* the ones to measure.
3. *Keep* **Compute metrics for each file separately** ticked for one row per file (plots, clips). *Untick* it to measure all the ticked files together as one cloud (tiles of one area).
4. With a DTM open (Exercise 5), heights above ground are computed for the clips; *Click* **OK**: the CSV has one row per clip, named after its file.

One row per file: the plot clips

file	point count	p95	canopy cover pct	dens first above 10m	strata 30m up	p95 minus p50
clip_1	5729	47.2	95.1	93.7	76.4	9.3
clip_10	4560	25.3	98.5	97.3	3.1	8.1
clip_11	2570	37.3	22.3	20.5	18.8	37.2
clip_12	1772	34.9	29.9	28.6	18.3	34.9
clip_2	6798	38.3	98.9	97.4	53.9	7.7
clip_3	3981	41.6	67.4	65.8	46.1	12.7
clip_4	4914	42.2	97.7	96.9	67.5	9.1
clip_5	2194	42.0	88.3	85.9	57.3	10.1
clip_6	6531	45.6	92.1	88.8	67.4	10.8
clip_7	3187	42.2	95.6	94.0	55.5	11.0
clip_8	5155	42.1	79.3	76.0	59.3	9.4
clip_9	5532	40.3	94.1	90.8	60.6	8.5

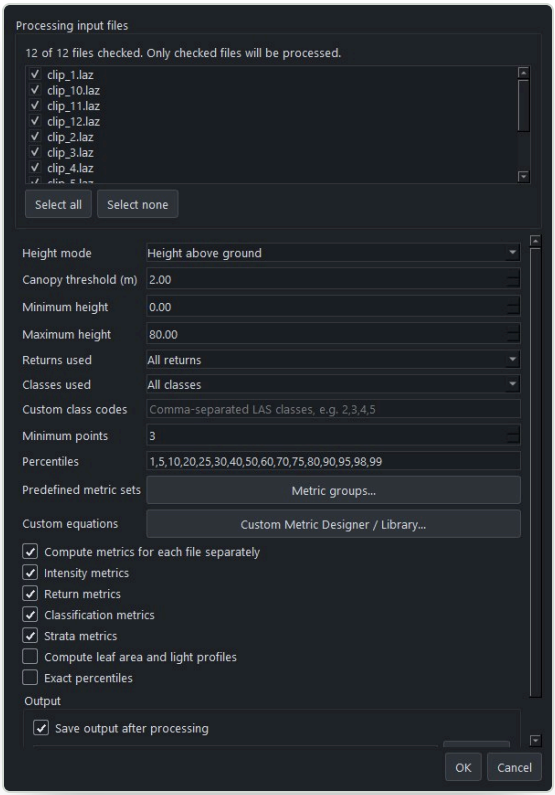


Figure 8.3 Cloud Metrics with twelve plot clips as input: one row per file.

Part 3: Metrics computed from the points

1. In the Cloud Metrics window, *Click* **Custom Metric Designer / Library…**.
2. *Click* **Add metric**, *type* a **Metric name** and its **Equation**. The equation works on the attributes of every point: **HAG** (height above ground), **Z** (elevation), **ReturnNumber**, **NumberOfReturns**, **Classification**, **Intensity**, **ScanAngle**, **R**, **G**, **B**,

TreeID.

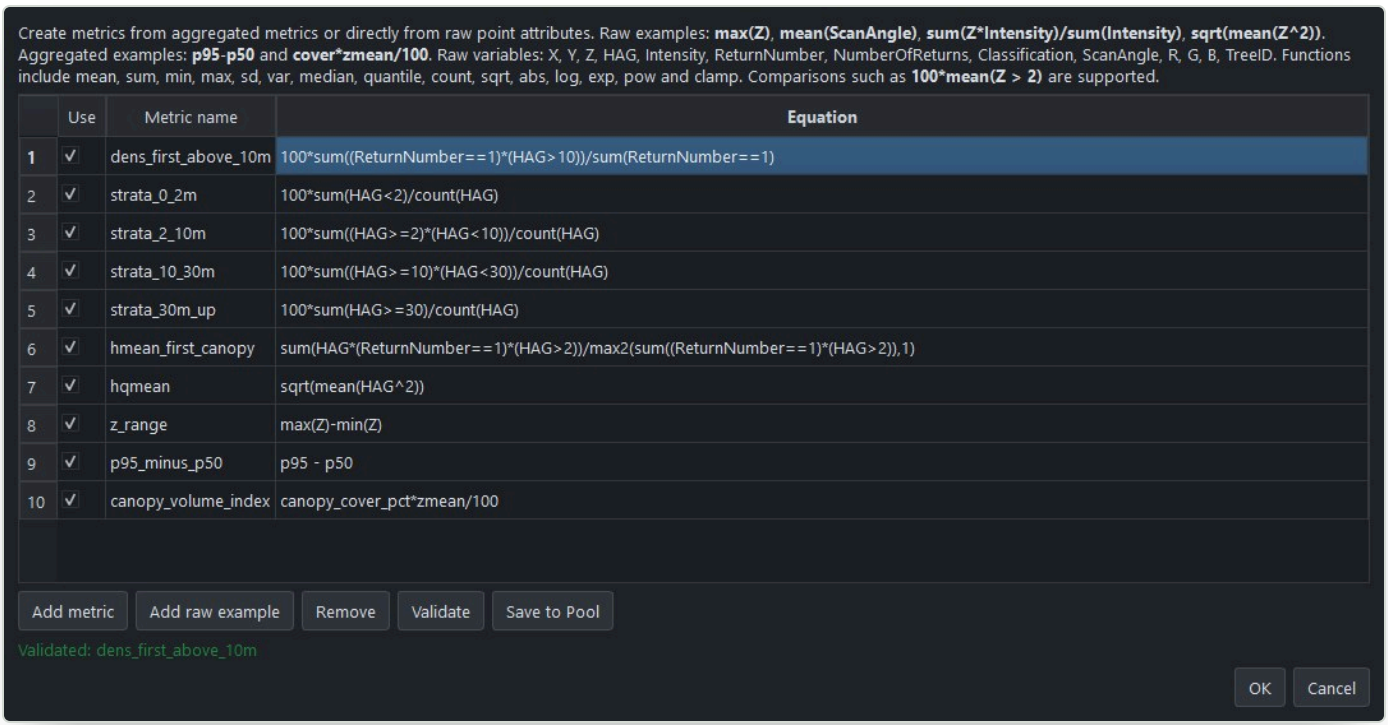


Figure 8.4 The Custom Metric Designer with the example metrics, each one validated.

Part 4: The example metrics

1. A comparison such as `HAG>10` is **1** for the points where it holds and **0** elsewhere: `sum()` of it counts those points, and multiplying two comparisons keeps the points where both hold. `count(HAG)` is the number of points.
2. *Type* the metrics of the table: a density of first returns above a high threshold (10 m), four height strata, the mean height of the canopy's first returns, a quadratic mean height and the elevation range.
3. *Select* each row and *Click* **Validate**; then *Click* **Save to Pool** to keep them in your own library: they are listed again the next time you open the designer, in Cloud, Grid and SilvaFlow metrics.

Metrics computed from the points

Metric name	Equation	Meaning
dens_first_above_10m	`100*sum((ReturnNumber==1)*(HAG>10))/sum(ReturnNumber==1)`	% of first returns higher than 10 m
strata_0_2m	`100*sum(HAG<2)/count(HAG)`	% of returns below 2 m
strata_2_10m	`100*sum((HAG>=2)*(HAG<10))/count(HAG)`	% of returns 2–10 m (understory)
strata_10_30m	`100*sum((HAG>=10)*(HAG<30))/count(HAG)`	% of returns 10–30 m
strata_30m_up	`100*sum(HAG>=30)/count(HAG)`	% of returns 30 m and higher
hmean_first_canopy	`sum(HAG*(ReturnNumber==1)*(HAG>2))/max2(sum((ReturnNumber==1)*(HAG>2)),1)`	mean height of first returns above 2 m
hqmean	`sqrt(mean(HAG^2))`	quadratic mean height
z_range	`max(Z)-min(Z)`	elevation range (terrain and trees)

Tip Functions: `sum`, `mean`, `min`, `max`, `sd`, `var`, `median`, `count`, `quantile(HAG,95)`, `sqrt`, `log`, `exp`, `abs`, `pow`, `max2(a,b)`, `clamp`. A cell where a filter keeps no point (no first return above 2 m) gets an empty value; wrap the denominator in `max2(…,1)` to get 0 instead.

Part 5: Metrics built from computed metrics

1. A metric can also combine metrics the tool has already computed, by their names in the CSV: **p95**, **p50**, **zmean**, **zmax**, **zsd**, **canopy_cover_pct**, **point_density**…
2. *Add* `p95_minus_p50 = p95 - p50` (the depth of the upper canopy) and `canopy_volume_index = canopy_cover_pct*zmean/100`.
3. *Click* **OK** in the designer, then **OK** in Cloud Metrics. Your metrics are added as columns of the output, after the standard ones.

Metrics built from computed metrics

Metric name	Equation	Meaning
p95_minus_p50	`p95 - p50`	depth of the upper canopy
canopy_volume_index	`canopy_cover_pct*zmean/100`	cover weighted by mean height

Note Computed from the points (Part 4) or from computed metrics (Part 5): both kinds can sit in the same set. The first reads every point; the second only the results.

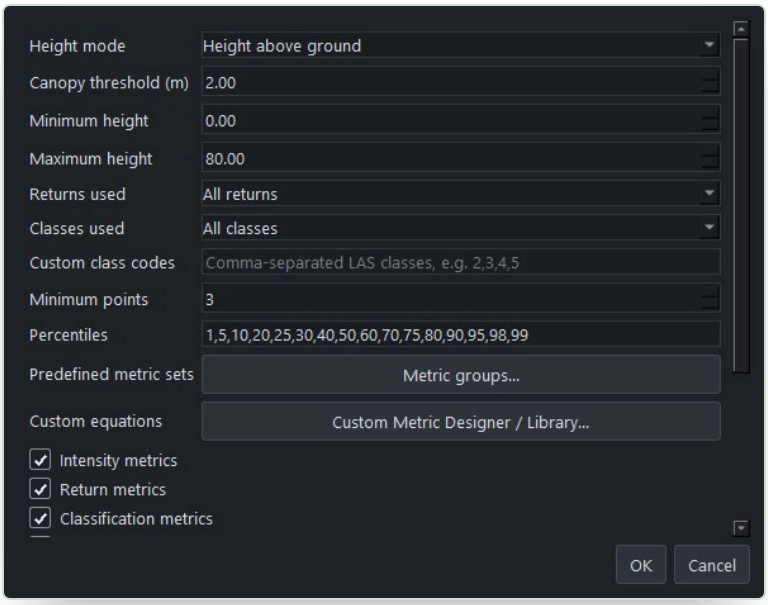


Figure 8.5 Cloud Metrics with the custom metrics set.

Part 6: The results

1. The Cloud Metrics CSV of the whole stand ends with your ten columns (table).

2. About half of the returns are within 2 m of the ground (open harvest units and the forest floor) and a third are above 30 m in the tall Douglas-fir: the strata say how the canopy is layered, which the mean height alone does not.

Cloud Metrics of the whole stand: your metrics

Metric	Value
dens_first_above_10m	48.1
strata_0_2m	45.2
strata_2_10m	4.3
strata_10_30m	18.5
strata_30m_up	31.9
hmean_first_canopy	30.4
hqmean	23.1
z_range	170.5
p95_minus_p50	30.6
canopy_volume_index	8.3

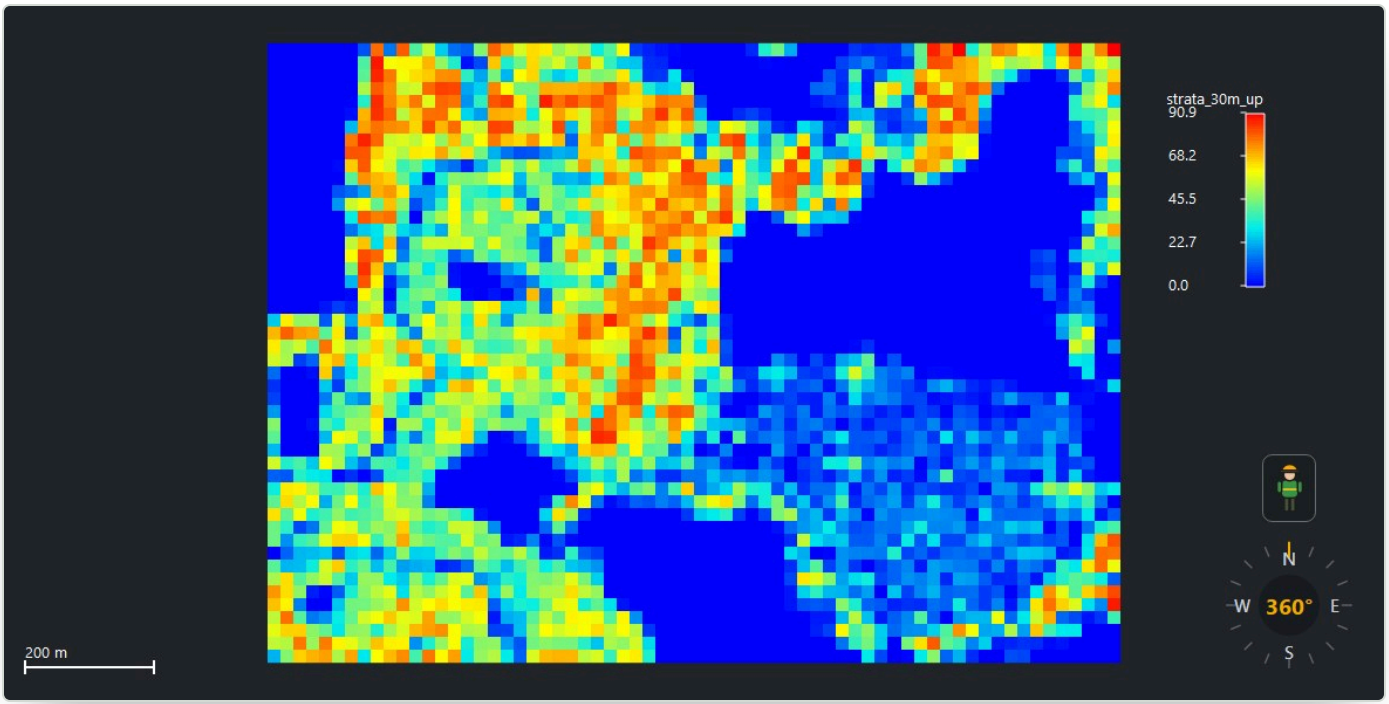


Figure 8.6 strata_30m_up for every 20 m cell (Part 7): the tallest trees.

Part 7: Grid metrics with your metrics, as maps

1. *Open* **Tools** › **Metrics** › **Grid Metrics** and *set* the **Grid size** to **20 m** (the size of the plots).
2. *Click* **Custom metrics…**: the same designer opens with your library. *Tick* the metrics to compute.
3. *Tick* **Create raster output (GeoTIFF)**, *choose* a folder such as **C:\SilvaLiDARAirExercise\03_Projects\cli_out\grid_rasters**, and *Click* **OK**.

4. One GeoTIFF is written per metric, yours included (**dens_first_above_10m_20m.tif**…). *Import* one: the 2D map shows the metric cell by cell, with its legend.

A few 20 m cells of grid_metrics.csv (your columns)

col	row	dens first above 10m	strata 0 2m	strata 2 10m	strata 10 30m	strata 30m up	p95 minus p50
0	0	31.4	65.8	0.0	11.1	23.1	35.7
1	0	57.2	42.7	5.4	5.4	46.5	25.1
2	0	91.0	9.2	3.6	21.3	65.9	8.3
3	0	91.2	11.7	2.8	16.0	69.4	9.1
4	0	93.5	11.9	3.1	13.5	71.5	6.1

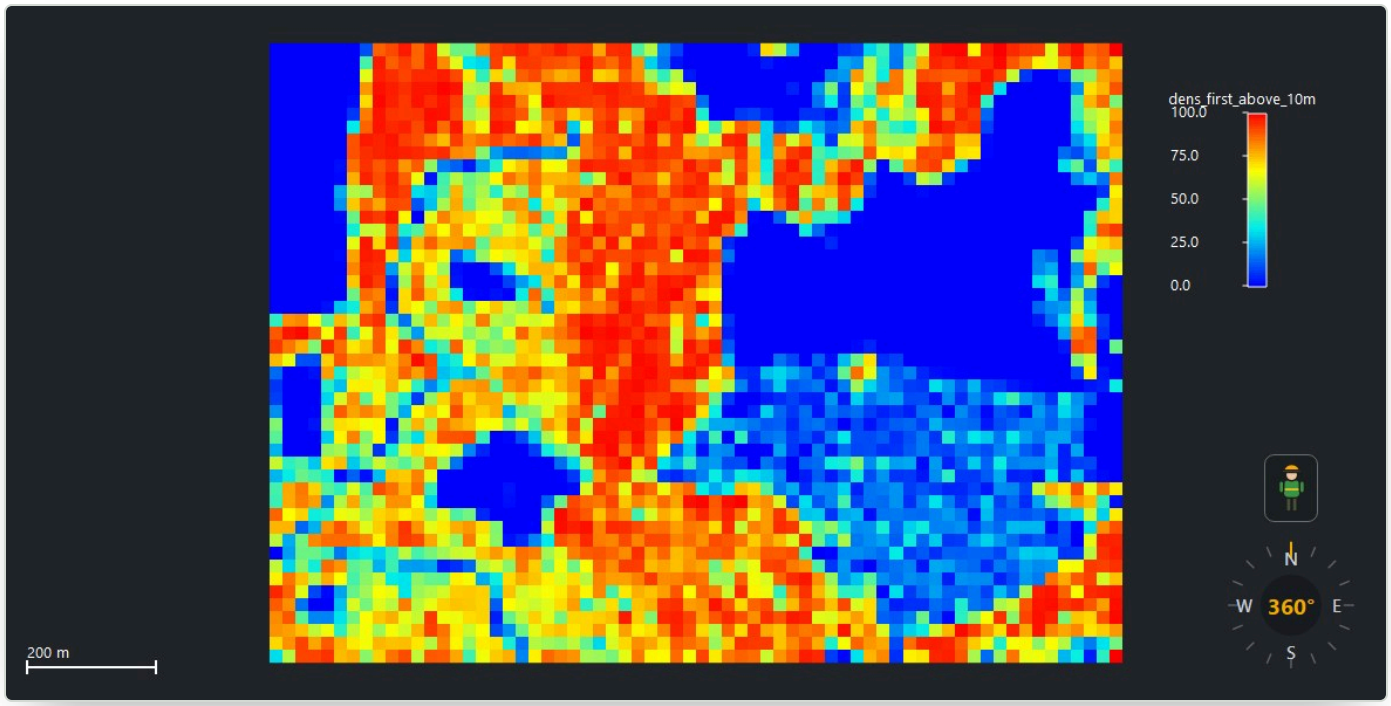


Figure 8.7 dens_first_above_10m: the share of first returns above 10 m in each 20 m cell.

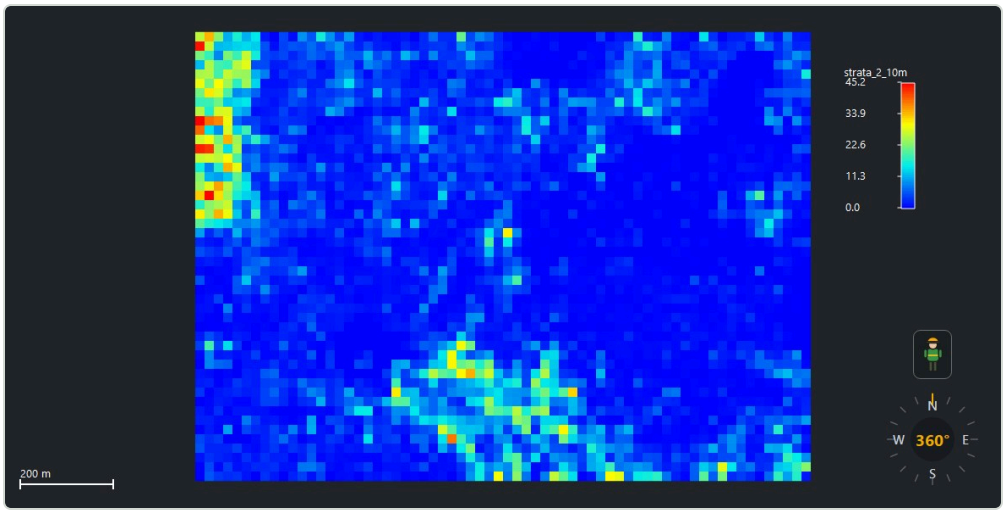


Figure 8.8 strata_2_10m: the share of returns between 2 and 10 m, the understory.

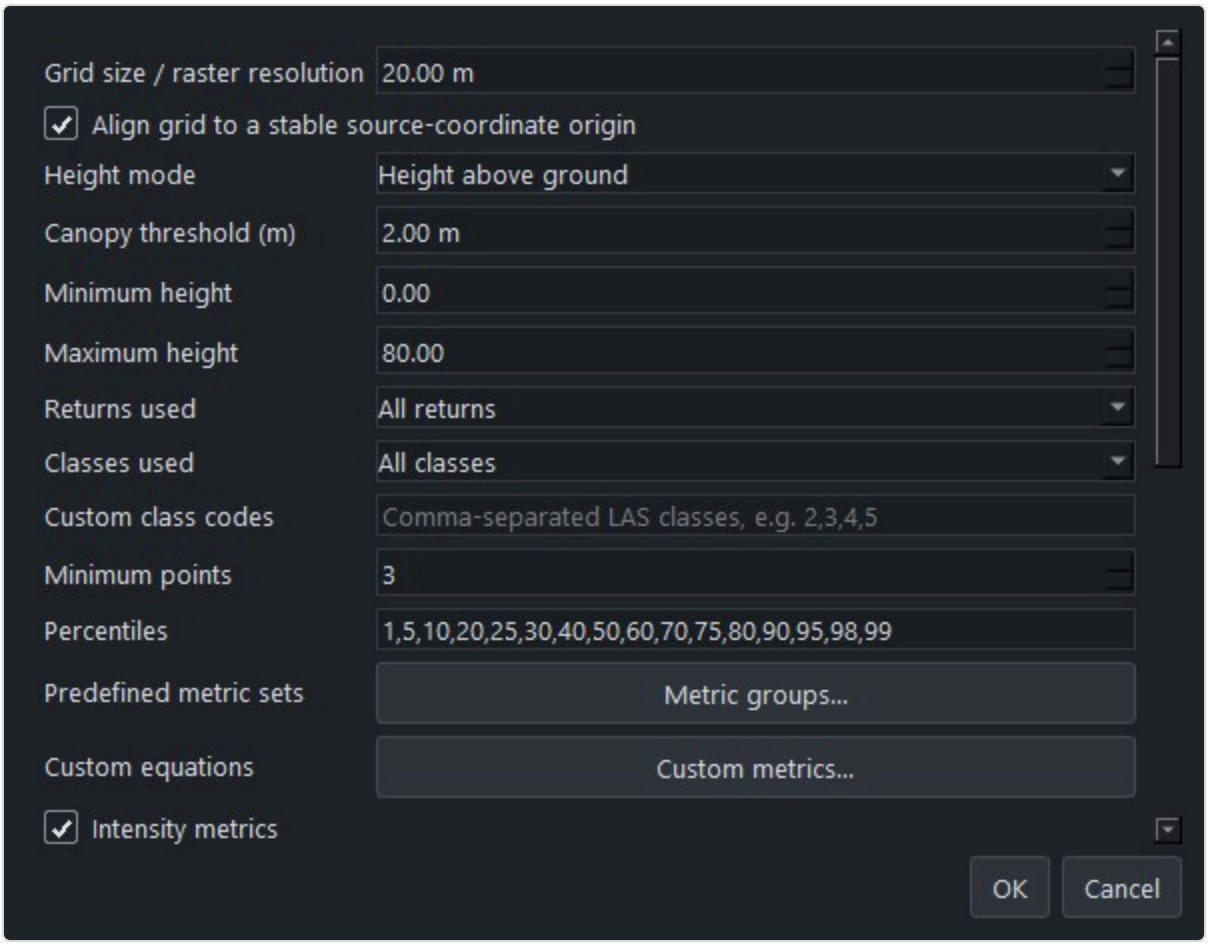


Figure 8.9 Grid Metrics: 20 m cells and the custom metrics.

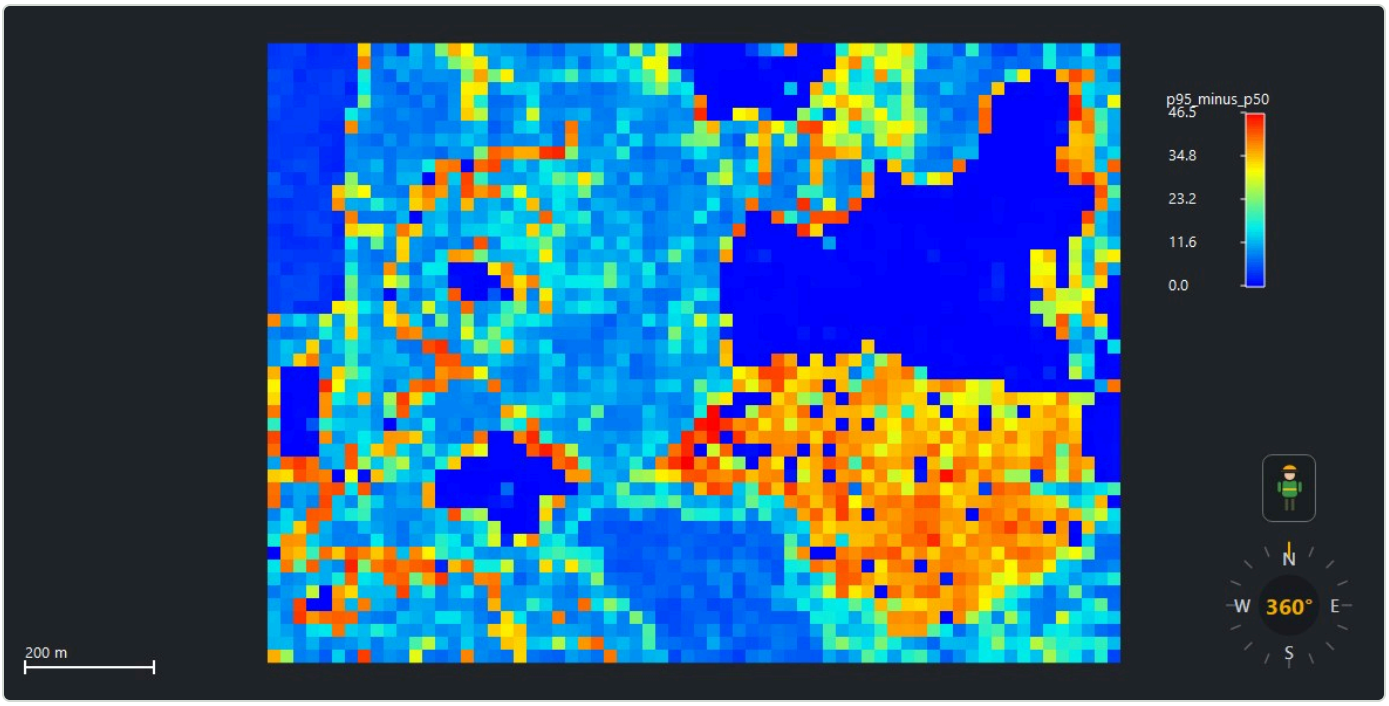


Figure 8.10 p95_minus_p50, built from two computed percentiles: deep crowns in red.

Part 8: Voxel metrics

1. *Open* **Tools** › **Metrics** › **Voxel Metrics** and keep **2 m × 1 m** voxels.
2. Under **Point attributes**, *tick* **Tree ID** › **Dominant value (mode)** (after Exercise 7) and *choose* **dominant_tree_id** as the colour; *Click* **OK**.
3. The voxels are drawn in 3D; the voxels of one tree share a colour.

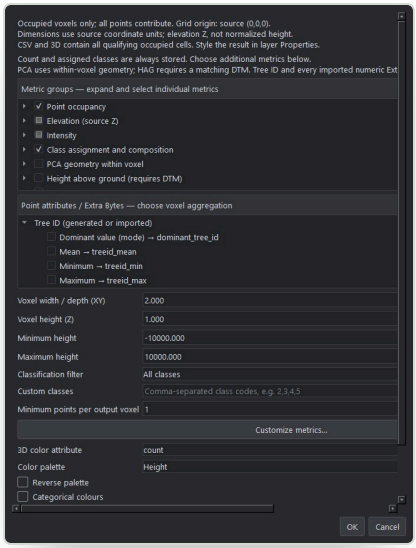


Figure 8.11 Voxel Metrics.

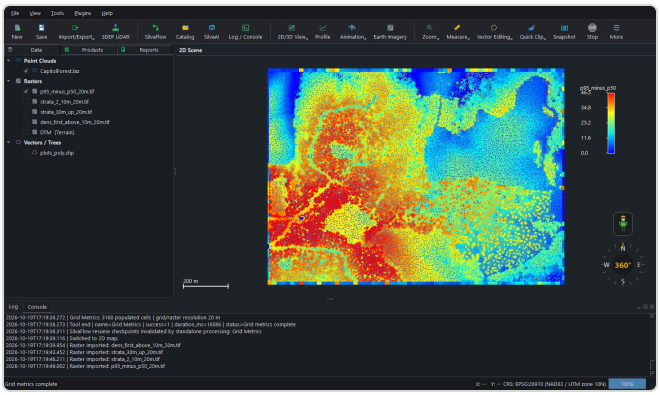


Figure 8.12 The custom-metric rasters in the Data panel.

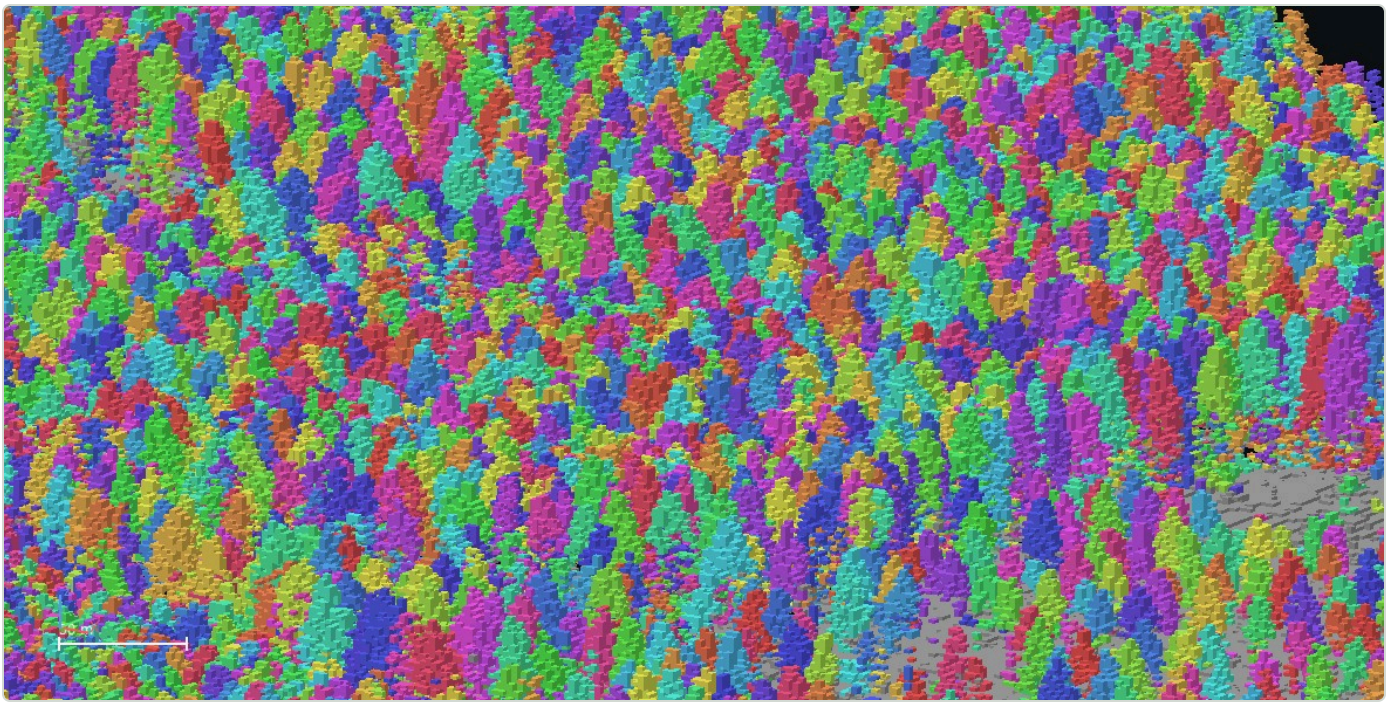


Figure 8.13 Voxels of 2 m × 1 m coloured by tree, close up: each crown is a stack of voxels of one colour.

Result You have standard metrics and your own metrics, computed from the points and from other metrics, for the stand and for every 20 m cell, as tables and maps.

Did you know? Grid Metrics always writes grid_metrics.csv; one GeoTIFF per metric is written only when you ask for rasters.

Check your understanding

1. Why should the grid cell match the area of the field plots?
2. Which metric describes canopy cover, and what does the 2 m threshold change?

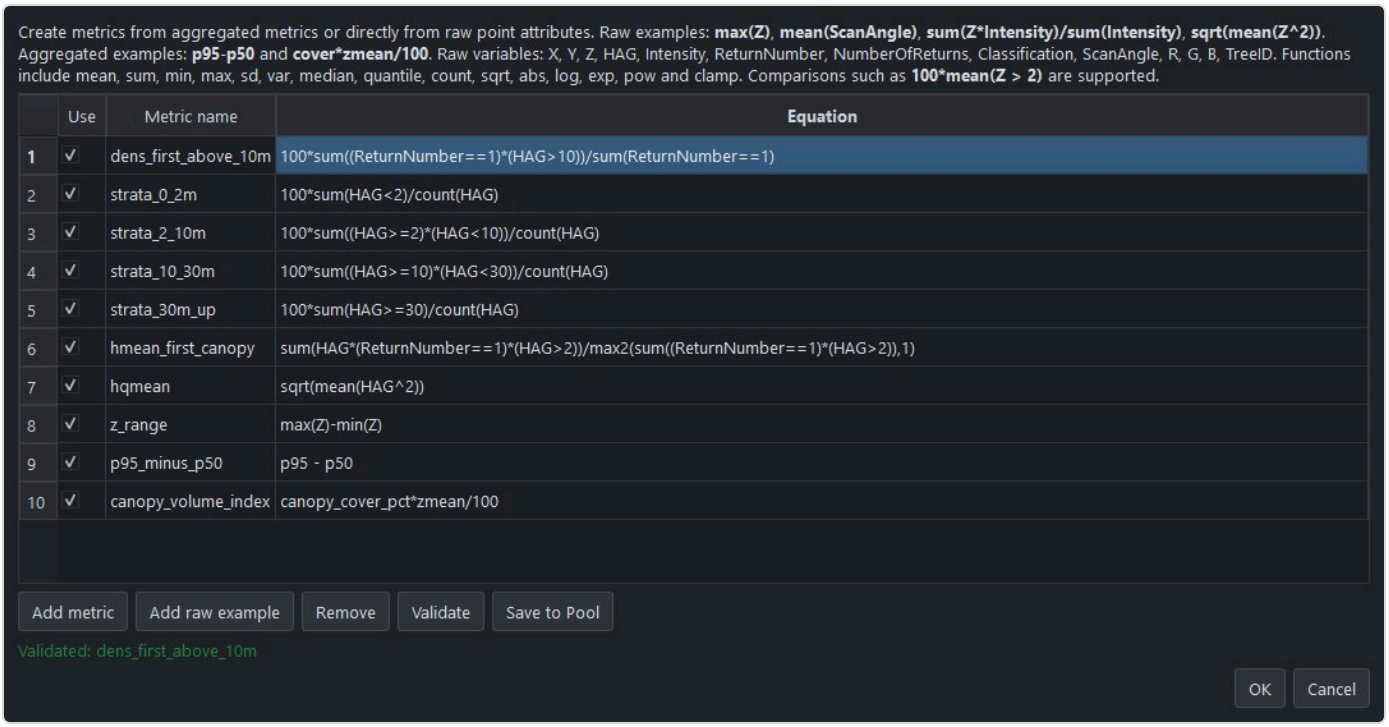


Figure 8.14 The same designer from Grid Metrics, with the same metrics.

09 EXERCISE 9
AREA-BASED MODELING AND MAPPING

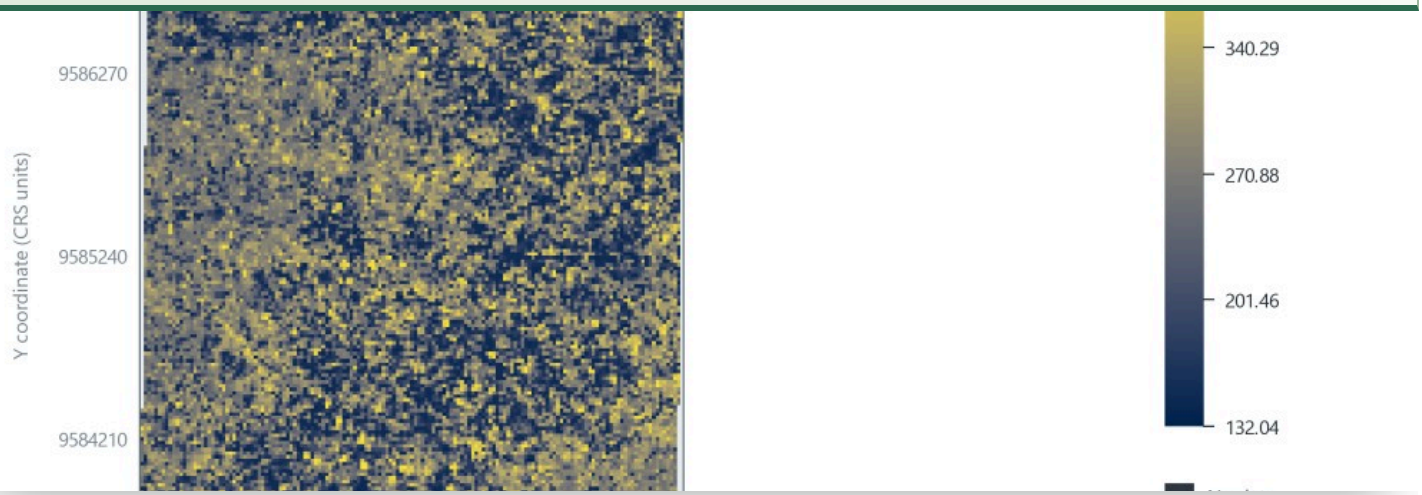


Figure 9.1 What you will make in this exercise.

Introduction

In this exercise you build a complete area-based model of forest biomass for Fazenda Cauaxi, in the eastern Amazon: you relate the field biomass of 85 plots to their LiDAR metrics, fit and validate a model, map it over a 20 m grid, estimate the mean biomass of the area with its uncertainty, and write the report.

You will learn to

- ✓ Relate field plots to LiDAR metrics
- ✓ Fit, compare and validate models
- ✓ Map a model and its uncertainty

Prerequisites

- Exercise 8 (metrics)
- The Fazenda Cauaxi tables of the exercise data, in **02_AmazonBrazil\03_Metrics**: the plot metrics with field biomass (**TAGBn**) and the 20 m grid metrics

Overview of major steps

1. Load the plots and choose the response
2. Choose the predictors
3. Fit and validate a model
4. Map it over the grid
5. Estimate the uncertainty
6. Write the report

Procedure

Part 1: The plot data

1. *Open* **Tools** › **Modeling** › **ALS Area-Based Modeling & Mapping…**.
2. In **01 Plot data**, *Click* **Import Plots Table…** and *select* **C:\SilvaLiDARAirExercise\01_Sites\02_AmazonBrazil\03_Metrics\CloudMetrics\plot_cloudmetrics.csv**.
3. *Choose* **TAGBn** (the field biomass) as the **Response column**. The preview shows one row per plot, 85 in all; *Click* **Continue**.

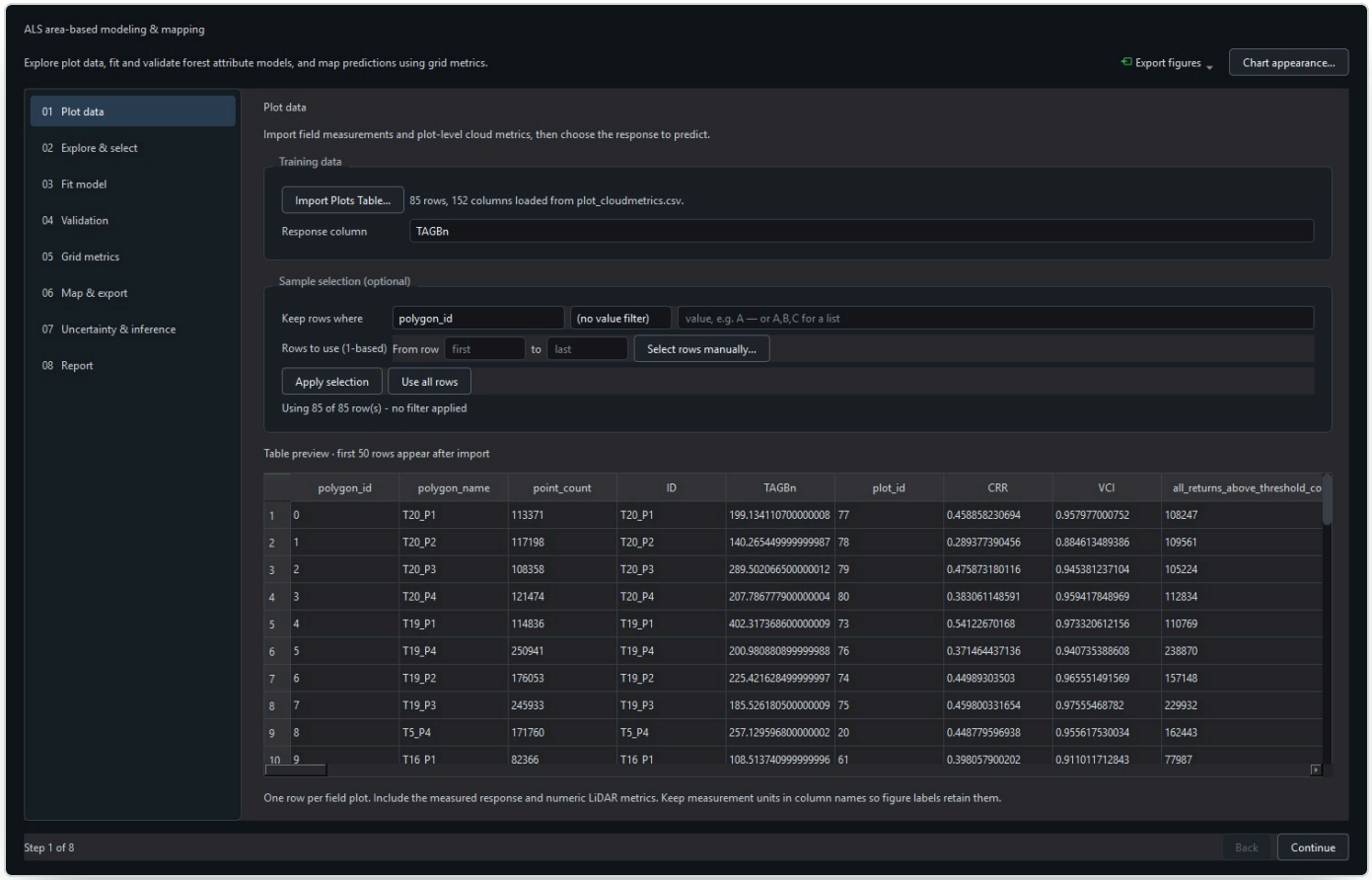


Figure 9.2 Step 1, Plot data: the 85 Fazenda Cauaxi plots, with the field biomass TAGBn as the response.

Part 2: Choose the predictors

1. In **02 Explore & select**, *Click* **Select none**, then *tick* four metrics: **zq95** (95th percentile of height), **zmean** (mean height), **zsd** (spread of heights) and **canopy_cover_pct**.
2. The other tabs show how each metric relates to the biomass and to the others; *Click* **Continue**.

> **Tip** Leave out identifiers such as **polygon_id** or **plot_id**: they are numbers, but not measurements of the forest.

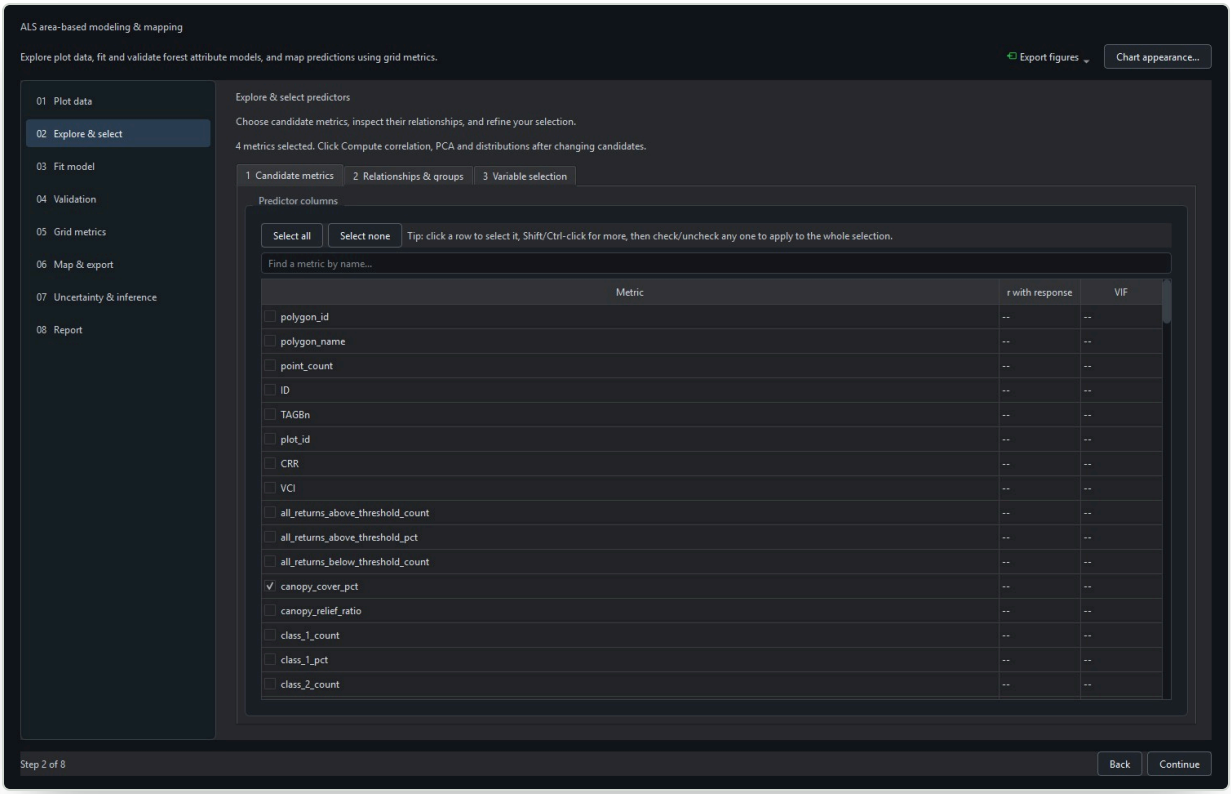


Figure 9.3 Step 2, Explore & select: four predictors ticked.

Part 3: Fit the model

1. In **03 Fit model**, *choose* **Random Forest** and keep **Leave-one-out** cross-validation.
2. *Click* **Fit Model**. The summary lists the variable importance and the fit statistics.

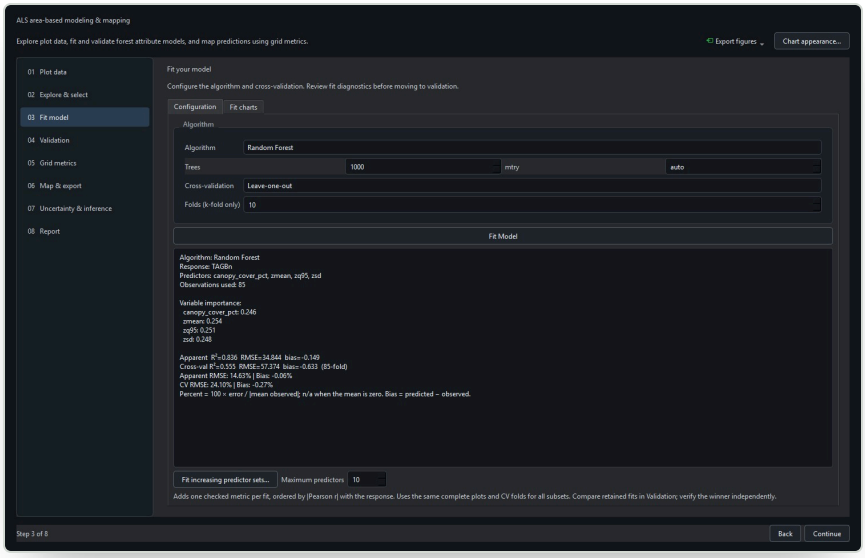


Figure 9.4 Step 3, Fit model: a Random Forest of TAGBn from the four metrics.

Part 4: Validate

1. **04 Validation** shows the biomass of each plot predicted without that plot against its field value, with the cross-validated R^2, RMSE and bias.
2. Here the model explains about 55 % of the variation between plots (cross-validated R^2 0.55), with an RMSE of about 24 % of the mean.



Figure 9.5 Step 4, Validation: predicted against observed biomass, leave-one-out.

Part 5: The prediction grid

1. In **05 Grid metrics**, *Click* **Add grid metric files…** and *select* **C:\SilvaLiDARAirExercise\01_Sites\02_AmazonBrazil\03_Metrics\GridMetrics\grid_metrics.csv**.
2. The columns **center_x** and **center_y** give the position of each cell; the grid has the same metric names as the plots.

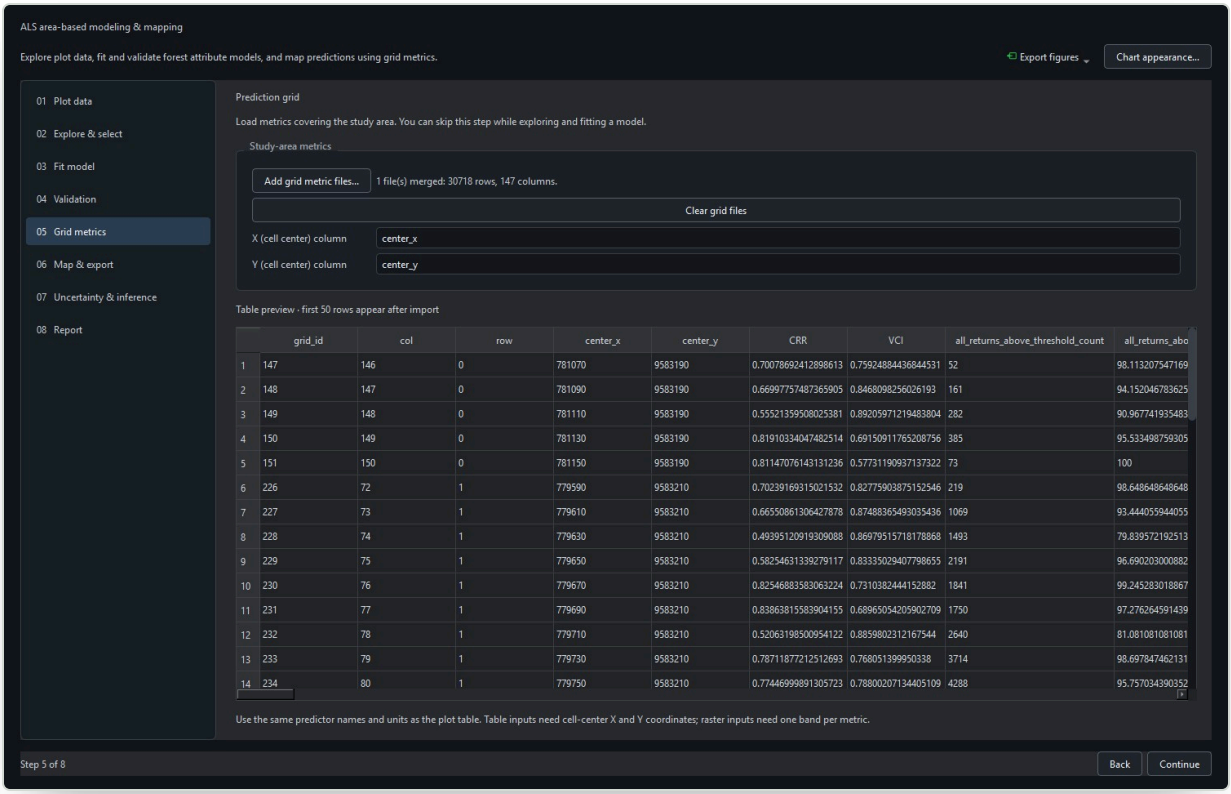


Figure 9.6 Step 5, Grid metrics: the 20 m cells of the area.

Part 6: Map the biomass

1. In **06 Map & export**, *choose* the fitted model and *set* the coordinate system to **EPSG:31982** (SIRGAS 2000 / UTM zone 22S).
2. *Click* **Apply to Grid (creates raster)…**: the predicted biomass of every 20 m cell is written as a GeoTIFF and drawn on the map.

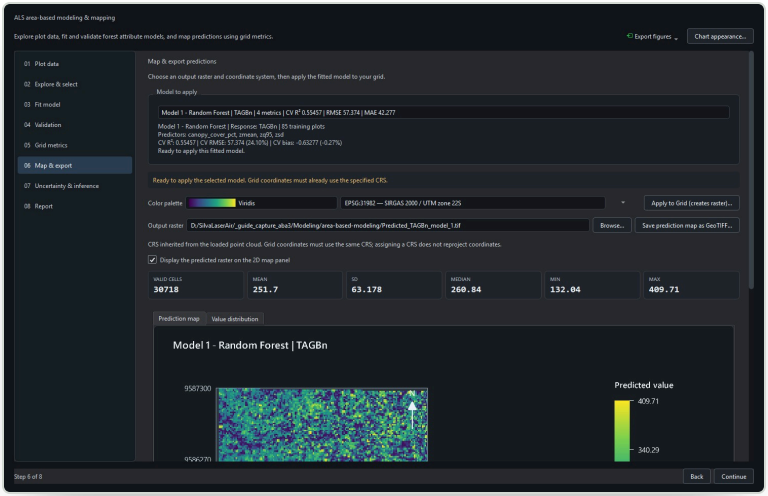


Figure 9.7 Step 6, Map & export: biomass predicted for every 20 m cell.

Part 7: Uncertainty

1. In **07 Uncertainty & inference**, keep **Entire mapped area** and *Click* **Calculate uncertainty**.
2. The table gives the mean biomass of the area, its standard error and its confidence interval, from bootstrap refits of the model.

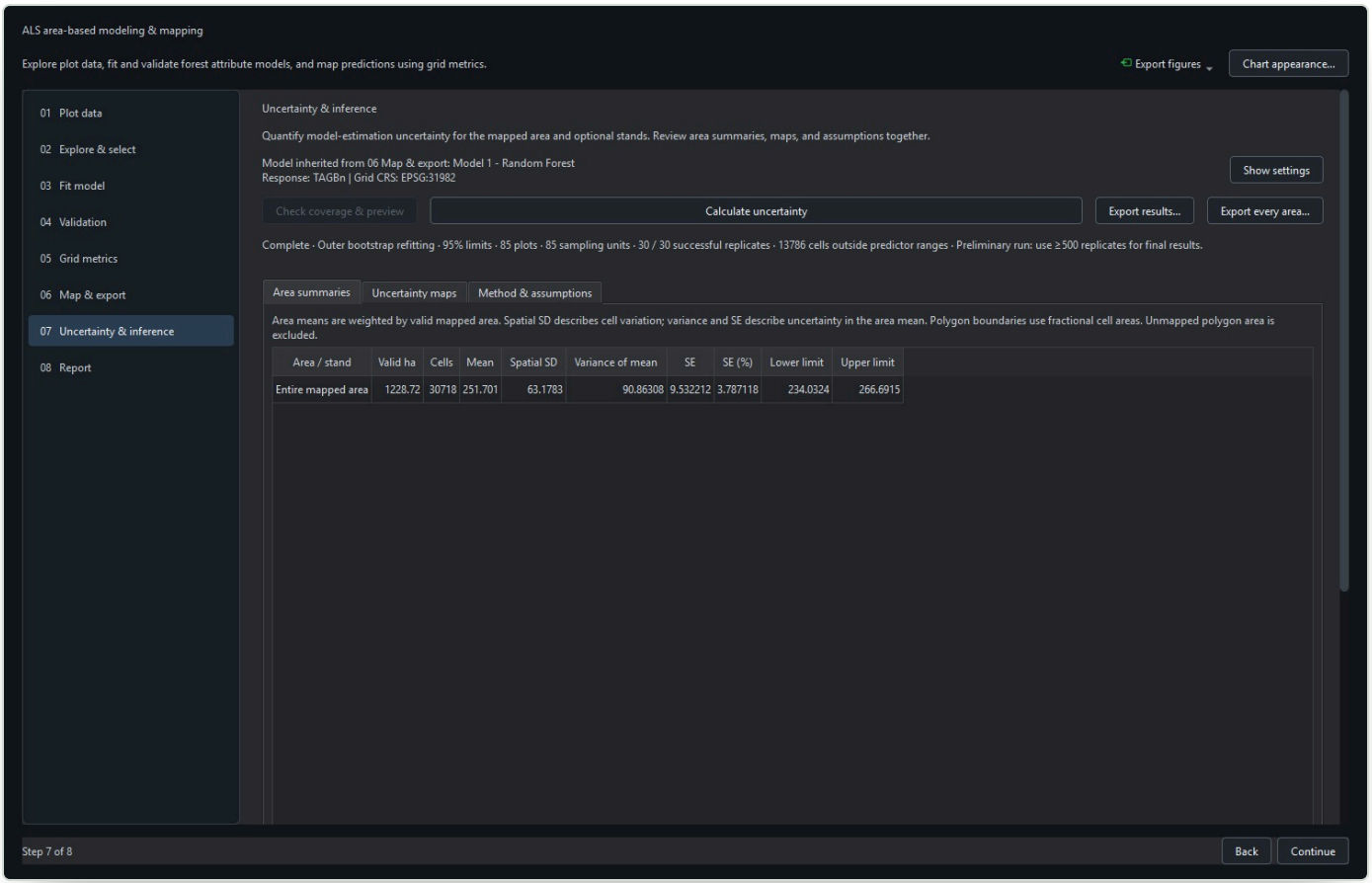


Figure 9.8 Step 7, Uncertainty: the mean of the area with its confidence interval.

Part 8: The report

1. In **08 Report**, *Click* **Export report (HTML/PDF)** and *choose* where to save it, for example in **03_Projects**.
2. The report gathers the data, the predictors, the model, its validation, the map and the uncertainty, as HTML and PDF.

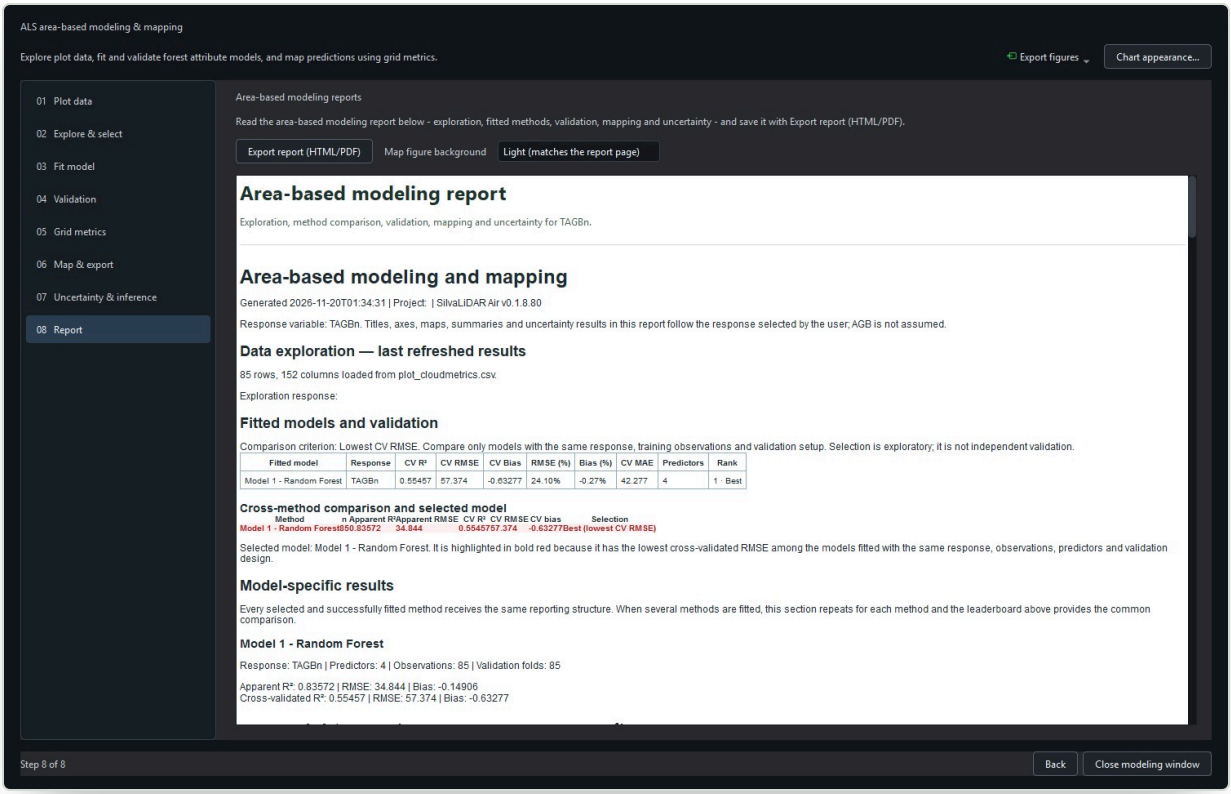


Figure 9.9 Step 8, Report: exported as HTML and PDF.

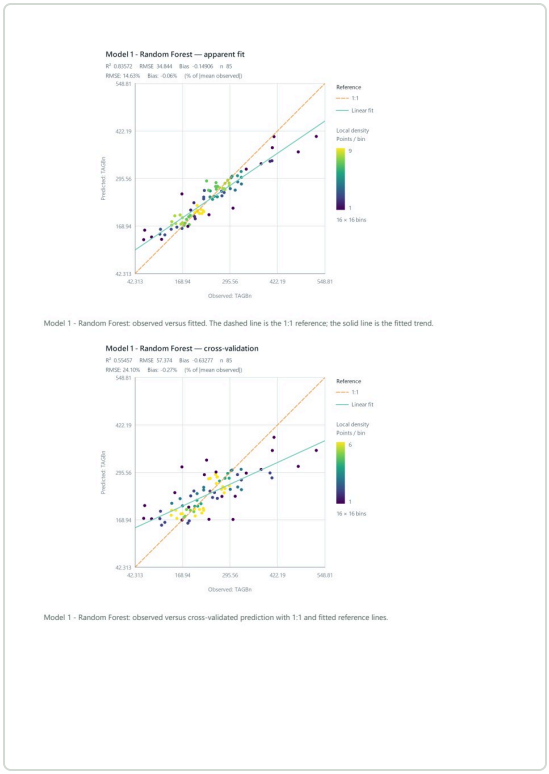


Figure 9.10 A page of the report.

Result You have a validated biomass model for Fazenda Cauaxi, a 20 m biomass map, the mean biomass of the area with its uncertainty, and the report.

Did you know? On the Fazenda Cauaxi plots, a Random Forest of four LiDAR metrics explains about 55 % of the variation in field biomass (leave-one-out).

Check your understanding

1. Why validate a model on plots that were not used to fit it?
2. What does the uncertainty map tell a forest manager?

10 EXERCISE 10 EARTH IMAGERY AND COLORIZING THE CLOUD

SilvaLiDAR Air 0.1.8.80

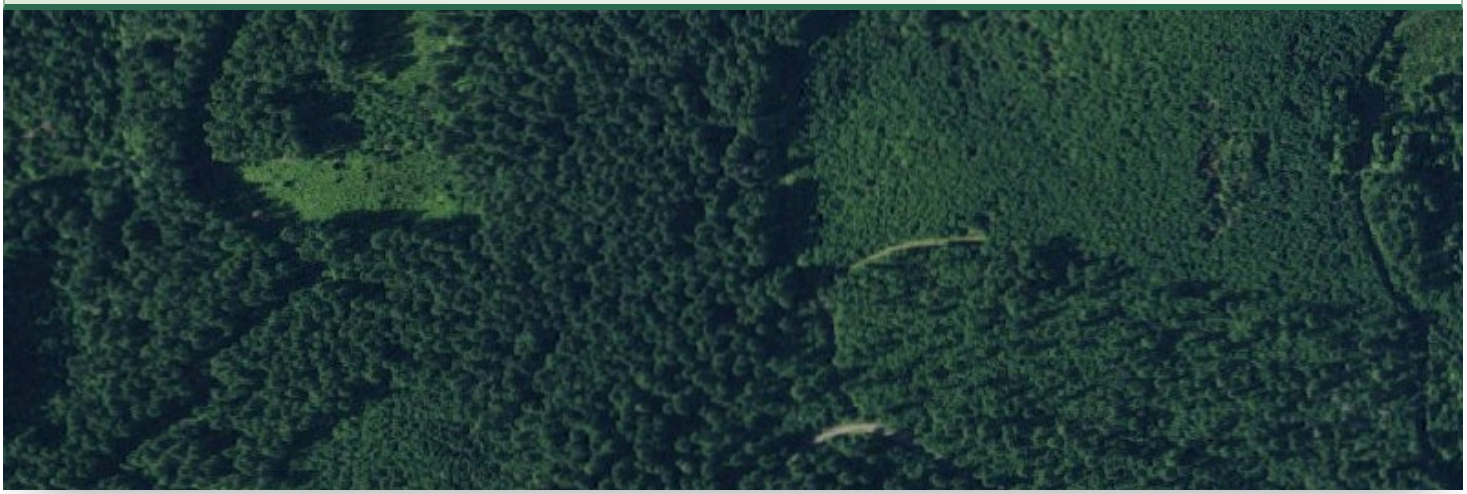


Figure 10.1 What you will make in this exercise.

Introduction

In this exercise you add imagery behind the map, drape it over the terrain, and write image colours into a point cloud.

You will learn to

- ✓ Add a live basemap
- ✓ Download imagery clipped to the project
- ✓ Write image colours into the points

Prerequisites

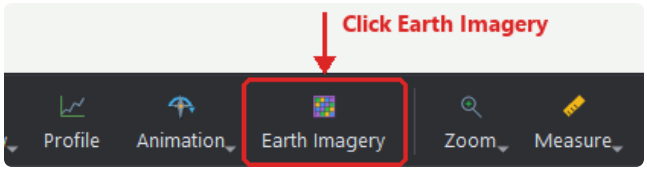
- Exercise 2
- An internet connection

Overview of major steps

1. Add a live basemap
2. Download imagery for the project
3. Colorize a point cloud

Procedure

Part 1: A live basemap



1. *Click* **Earth Imagery**.
2. *Choose* **USGS NAIP / Imagery Only** and **Dynamic global basemap**, and *Click* **Add imagery**.
3. The imagery appears behind the cloud and follows every zoom and pan.

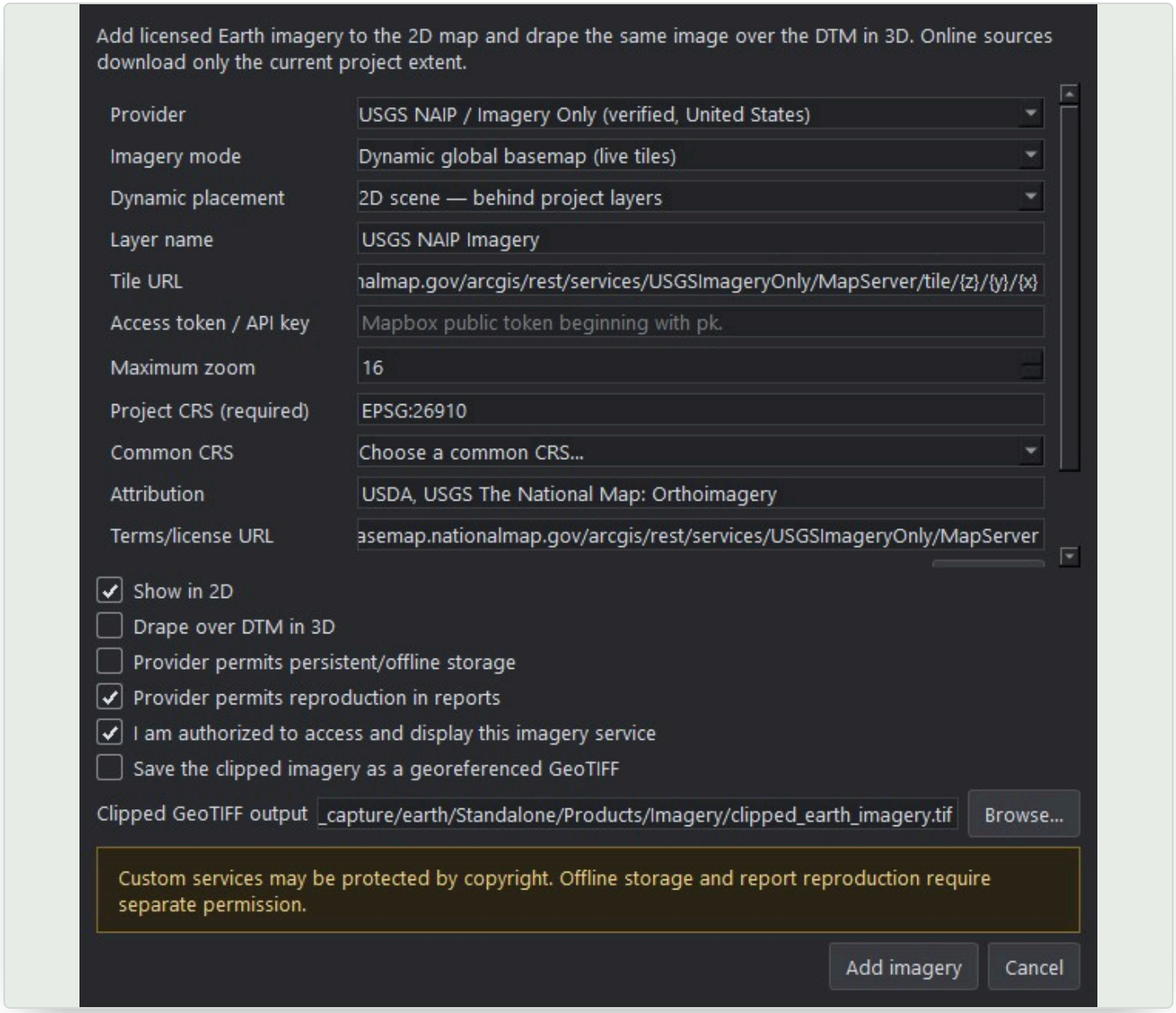


Figure 10.2 The Earth Imagery window.



Figure 10.3 NAIP behind the example cloud.

Part 2: Imagery clipped to the project

1. *Open* **Earth Imagery** again and *choose* **Clip to current project extent**.
2. *Tick* **Drape over DTM in 3D** and *Click* **Add imagery**. The clipped image becomes a raster layer, draped over the terrain in 3D.

Important Imagery services have their own terms. Download, store or publish imagery only as its provider allows.



Figure 10.4 NAIP imagery clipped to the project, under the point cloud.

Part 3: Your own tile source (Custom XYZ)

1. Any other imagery service you are authorized to use can be added through its tile URL. *Open* **Earth Imagery** and *choose* **Custom XYZ tiles**.
2. *Paste* the service's tile URL into **Tile URL**. `{z}`, `{x}` and `{y}` stand for each tile's zoom level and position; a key the service needs goes in **Access token / API key**.
3. *Fill in* **Attribution** and **Terms/license URL** as the provider asks, *tick* **I am authorized to access and display this imagery service**, and *Click* **Add imagery**.
4. Only the presets in the list are built into SilvaLiDAR Air. A custom source is your own choice, under that provider's terms.

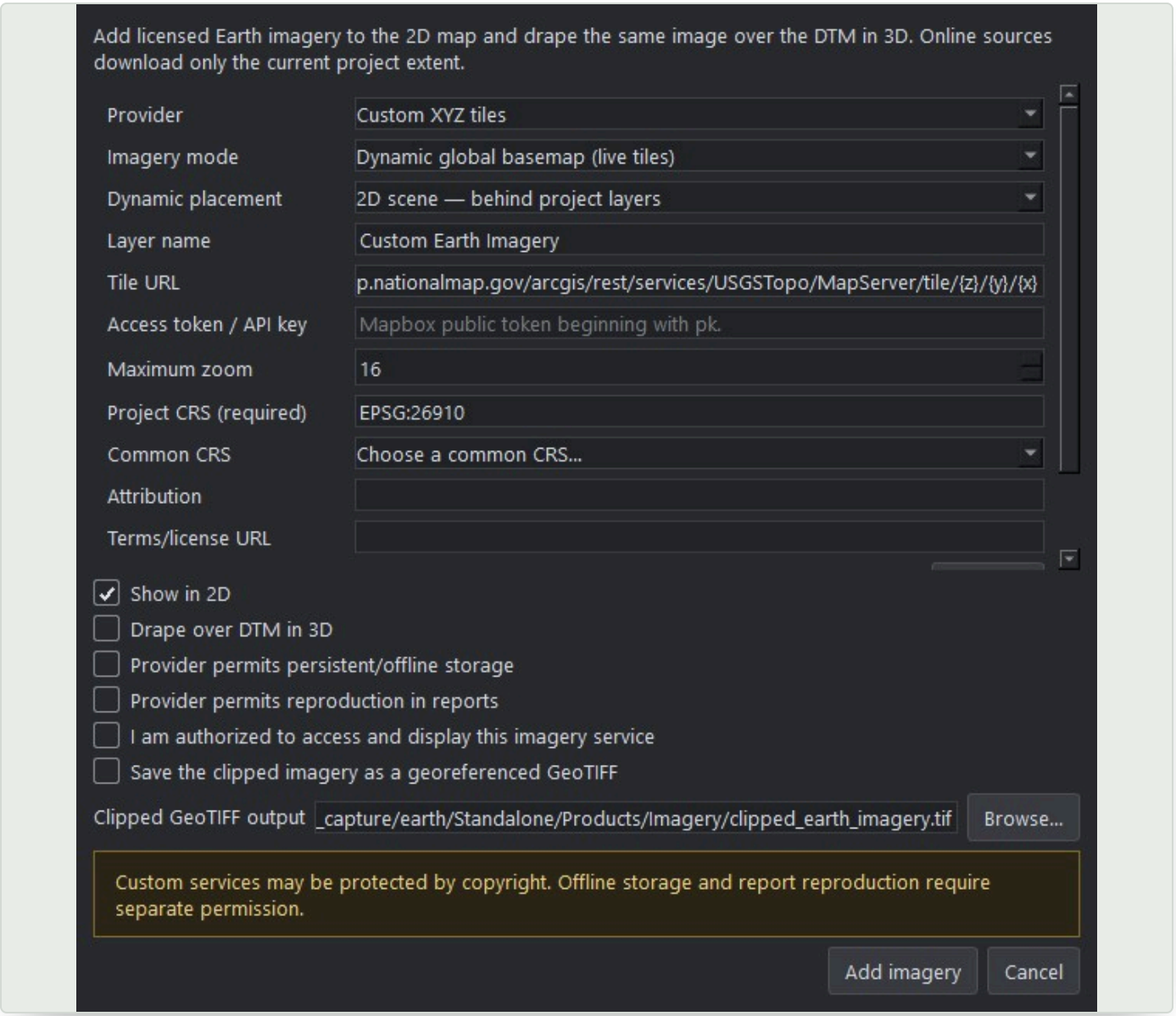


Figure 10.5 Custom XYZ tiles with a tile URL typed in: here the public USGS topographic map.



Figure 10.6 The USGS topographic map added through Custom XYZ, as a live basemap under the point cloud.

Part 4: Colorize

1. *Open* **Tools** › **Point Cloud** › **Colorize LAS/LAZ**.
2. *Choose* the point cloud and the imagery layer, *check* the CRS of each, and the output folder.
3. *Click* **Colorize point cloud**. The new LAZ shows the imagery colours in RGB mode.

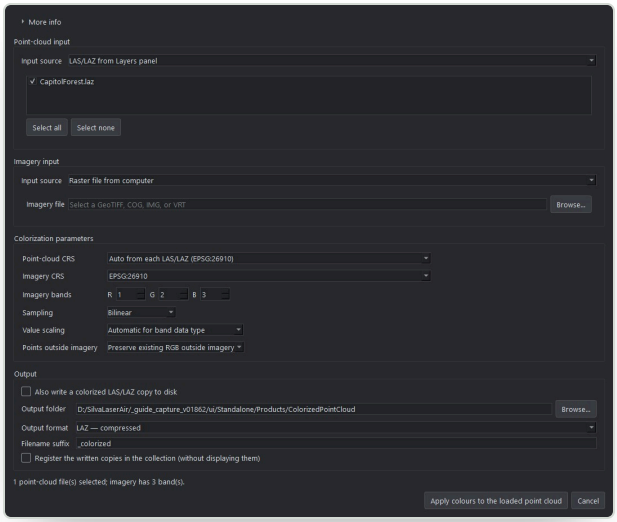


Figure 10.7 Colorize LAS/LAZ.

Result You can use online or local imagery in 2D, in 3D and as point colours.

Did you know? The USGS NAIP tile service ends at zoom 16, about 2 m per pixel; use a local orthophoto for finer work.

Check your understanding

1. Why does Earth Imagery need the coordinate system of the data?
2. When would you colorize from a local orthophoto instead of an online service?

11 EXERCISE 11 WORKFLOWS WITH SILVAFLOW

SilvaLiDAR Air 0.1.8.80

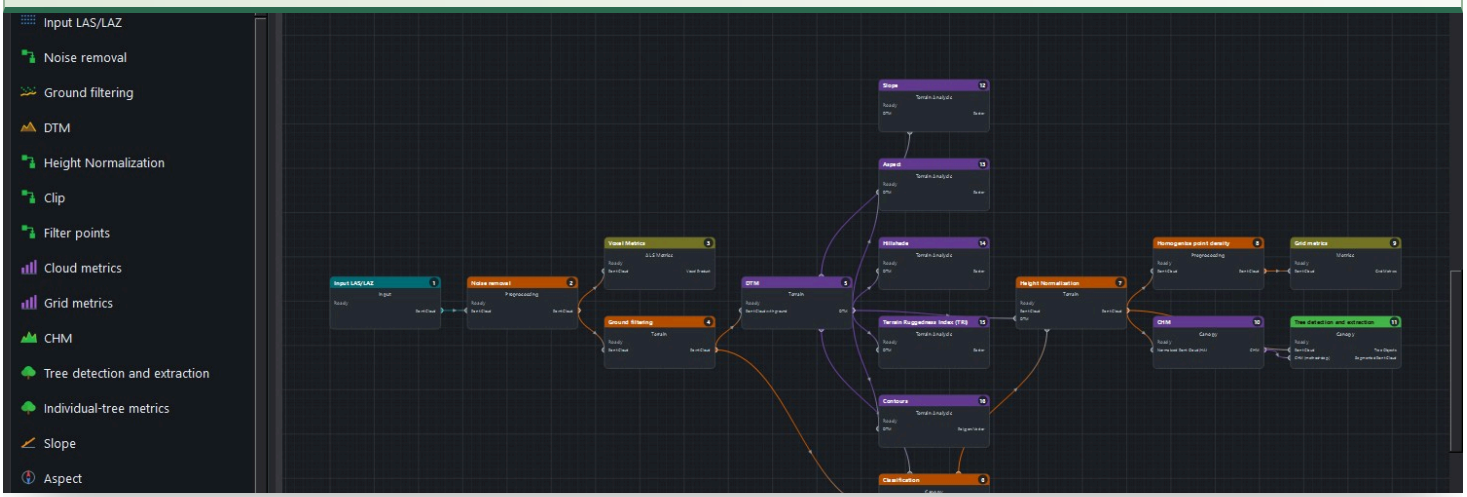


Figure 11.1 What you will make in this exercise.

Introduction

In this exercise you run the whole chain of Exercises 5–7 as one SilvaFlow workflow and get its processing report.

You will learn to

- ✓ Build a workflow from tools
- ✓ Set the parameters of each box
- ✓ Run it and read the processing report

Prerequisites

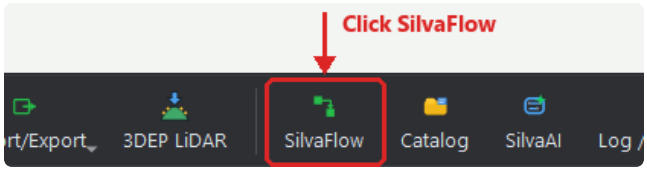
- Exercise 2

Overview of major steps

1. Open SilvaFlow and build a workflow
2. Set a box's parameters
3. Run it and open the report

Procedure

Part 1: Build the workflow



1. *Click* **SilvaFlow**.
2. *Click* **Template** for the default forest workflow, or *drag* tools from the **TOOLS** list and *connect* them left to right: Input LAS/LAZ › Ground filtering › DTM › Height Normalization › CHM › Tree detection.
3. *Click* **Arrange** and **Validate**.

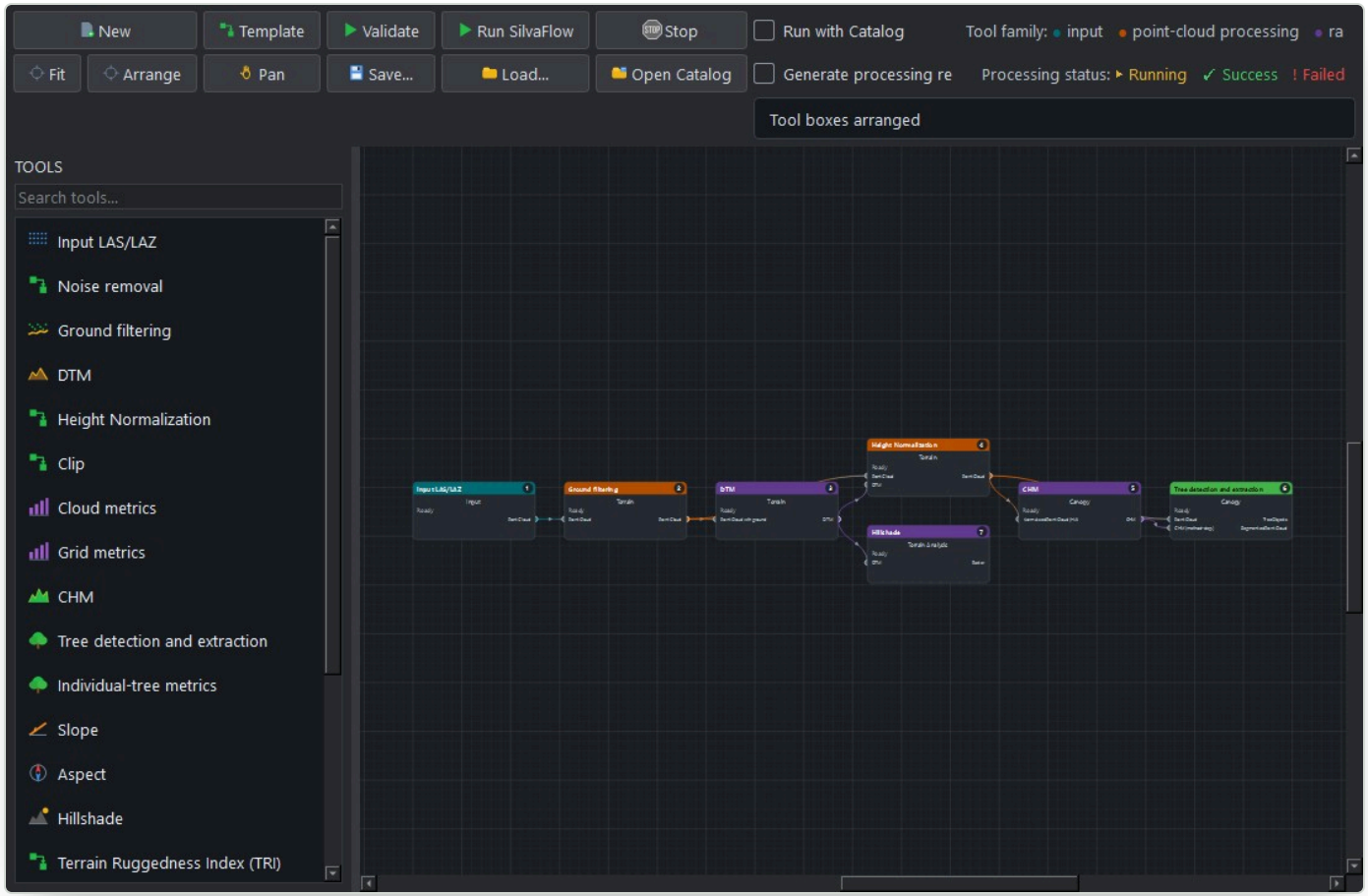


Figure 11.2 SilvaFlow after Template and Arrange: Input LAS/LAZ, Ground Filtering, DTM, Height Normalization (with Hillshade from the DTM), CHM and Tree detection, left to right.

Part 2: Set the parameters

1. *Click* a box to open its settings: the same parameters as the standalone tool.
2. *Tick* **Display final product** on the boxes whose results you want to see at the end.

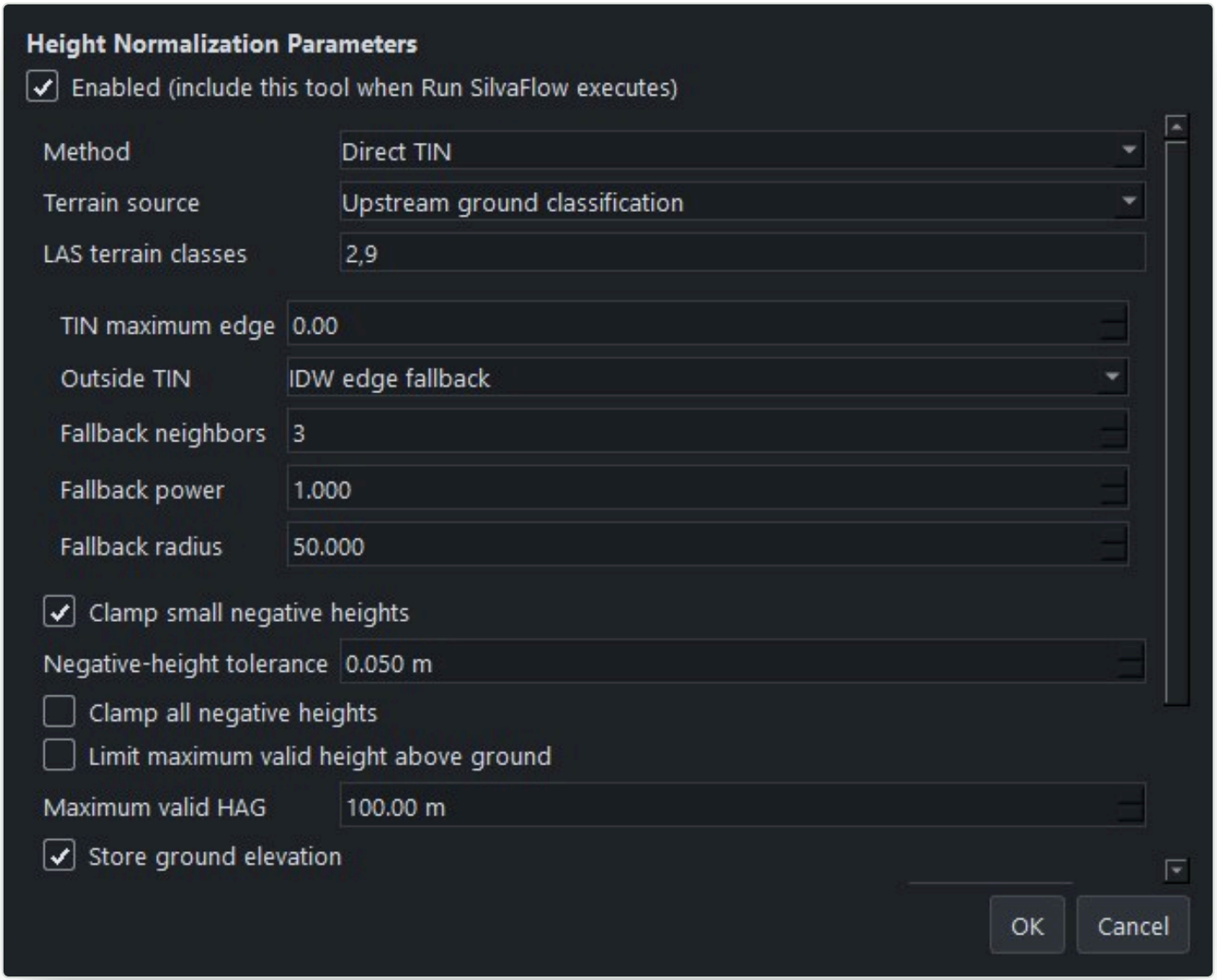


Figure 11.3 The settings of a box.

Part 3: Run and report

1. *Tick* **Generate processing report after run** and *Click* **Run SilvaFlow**.
2. Each box shows its progress and turns green when done. The products appear in the Data panel.
3. *Open* the report from the **Reports** panel. *Click* **Save…** to keep the workflow for other data.

> **Tip** A re-run only recomputes the boxes whose inputs or settings changed.

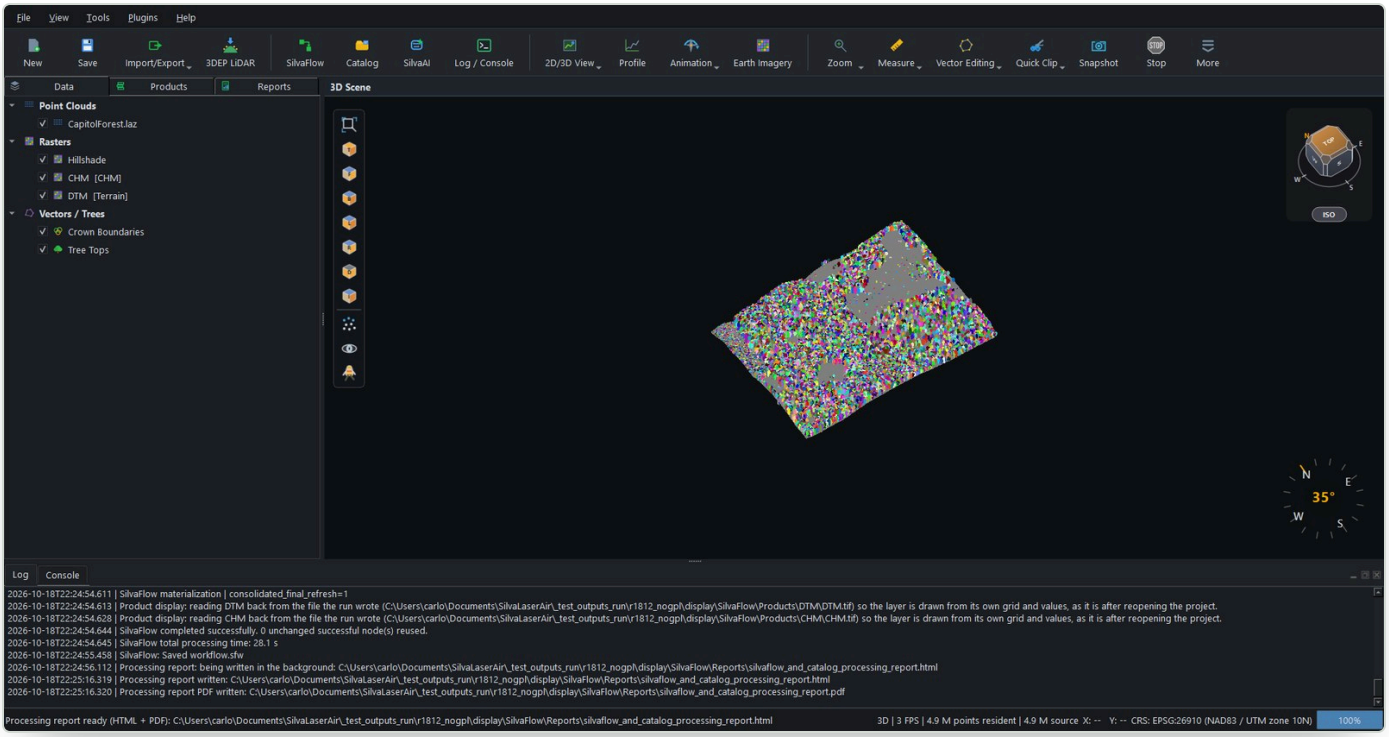


Figure 11.4 The products of the run.

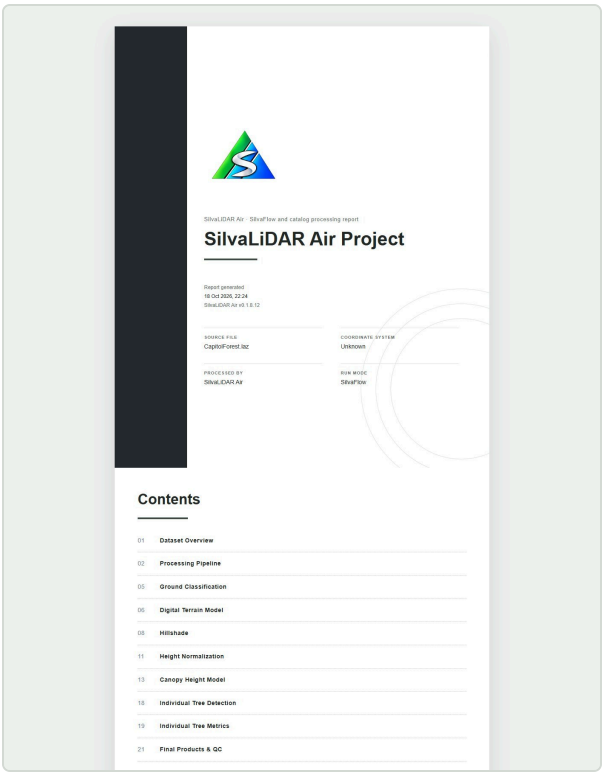


Figure 11.5 The processing report.

Result You have a saved workflow that turns a LAS/LAZ into terrain, canopy and tree products in one run, with a report.

Did you know? A re-run only recomputes the boxes whose inputs or settings changed; the others are reused.

Check your understanding

1. What happens when you change one setting and run the workflow again?
2. Which boxes would you add to produce plot metrics as well?

12 EXERCISE 12 LARGE AREAS WITH SILVAFLOW + CATALOG

SilvaLiDAR Air 0.1.8.80

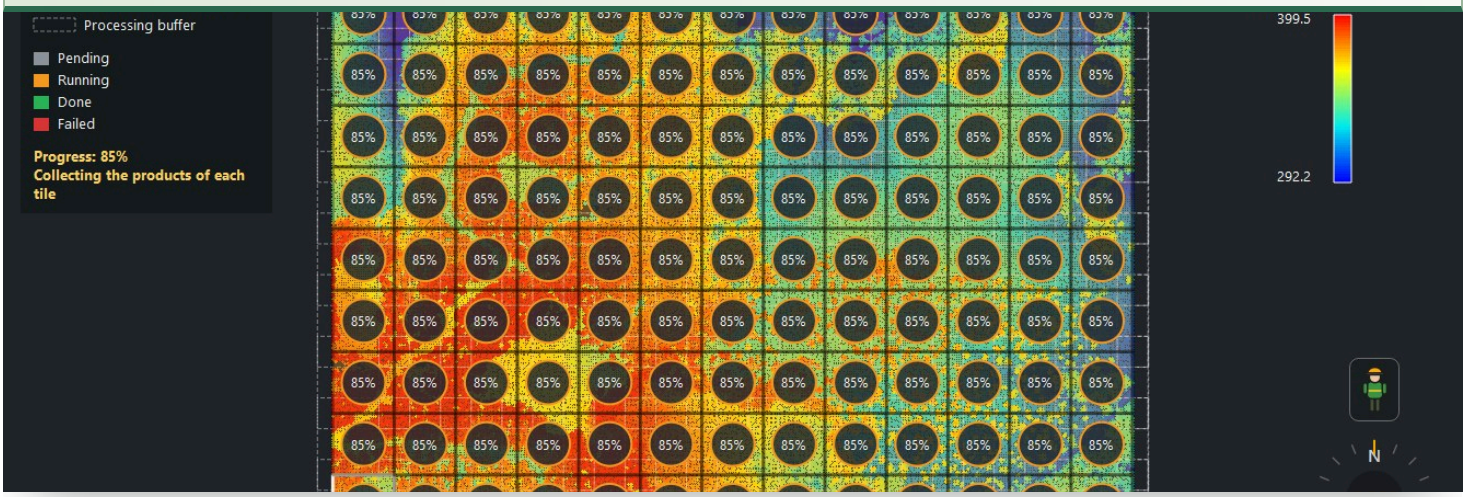


Figure 12.1 What you will make in this exercise.

Introduction

In this exercise you run the same workflow tile by tile with Catalog, as you would for an area much larger than the example.

You will learn to

- ✓ Plan processing tiles and buffers
- ✓ Run a workflow tile by tile
- ✓ Follow the progress of each tile

Prerequisites

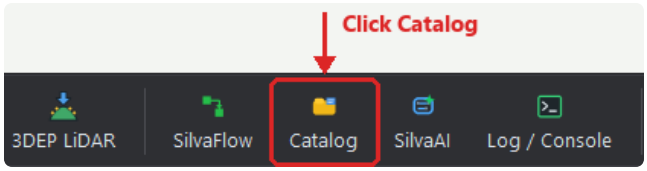
- Exercise 11 (a workflow in SilvaFlow)

Overview of major steps

1. Open the Catalog panel
2. Plan the tiles
3. Run and follow the progress

Procedure

Part 1: The tile plan



1. *Click* **Catalog**.
2. *Keep* the **Tile size** at **500 m**, the default, and the **automatic buffer**.
3. *Click* **Build**: the tiles and their buffers are drawn on the map.

> **Tip** Each tile reads a buffer around it, so products join without seams. Large tiles repeat less work in their buffers than small ones.

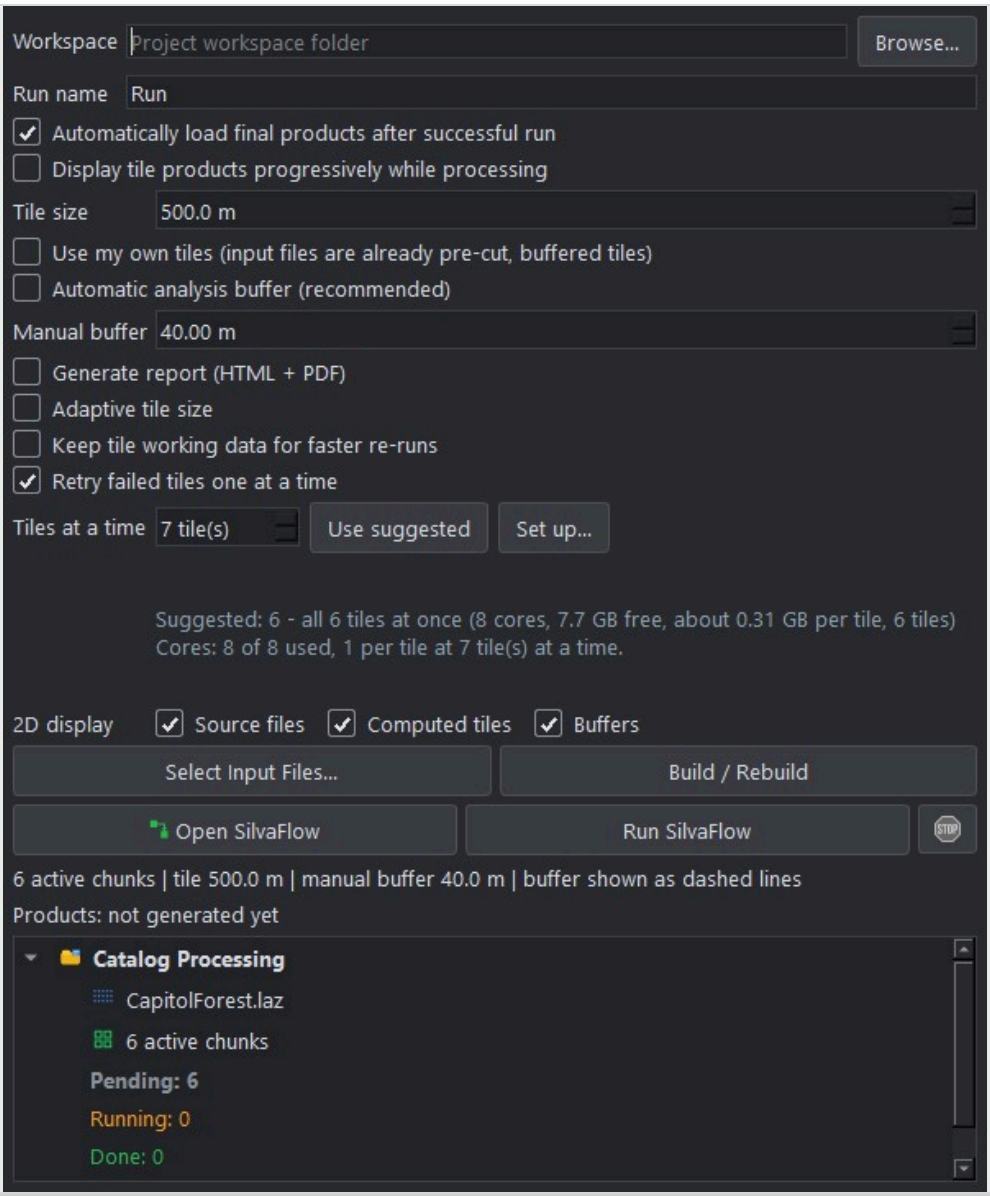


Figure 12.2 The Catalog panel with 500 m tiles.

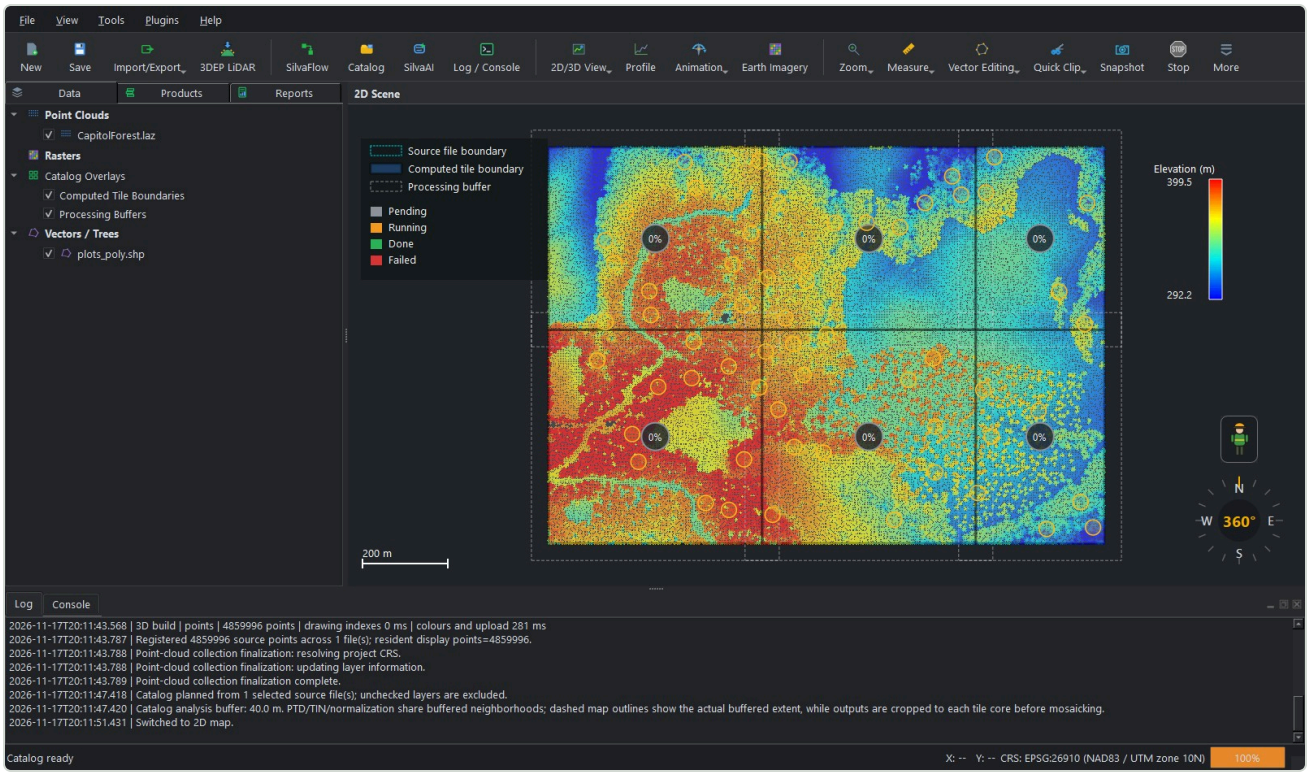


Figure 12.3 The 500 m tiles and their buffers on the map.

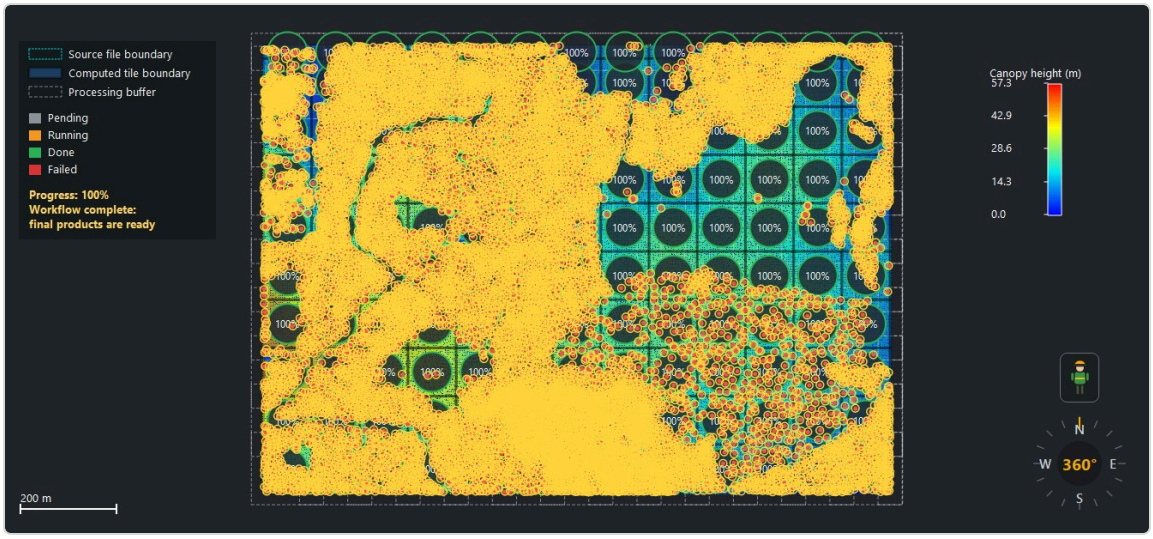


Figure 12.4 A Catalog run finished: every tile done, the products merged.

Part 2: Run

1. In SilvaFlow *tick* **Run with Catalog** and *Click* **Run SilvaFlow** (or **Run** in the Catalog panel).
2. *Watch* the map: each tile shows **Pending**, **Running** with its percentage, then **Done**.
3. At the end the products of all tiles are merged and the report is written.

> **Note** A tile waits at 85 % while the other tiles finish, and at 95 % while the final products are built.

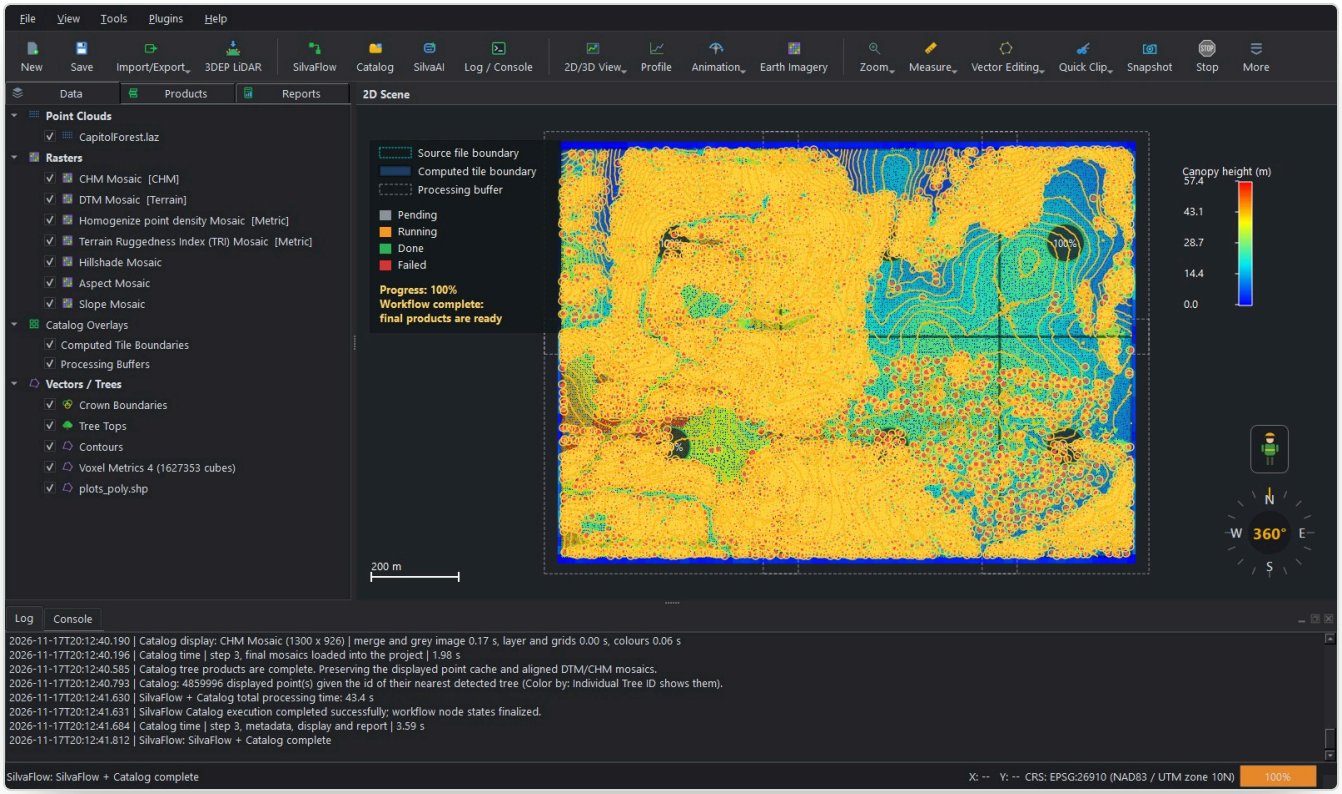


Figure 12.5 The run has ended: every 500 m tile is Done and the merged products are in the Data panel (the whole workflow took about 45 s on the example data).

Part 3: The same from the command line

Command line

```
SilvaLiDARAirCLI.exe --tool catalog-pipeline --input-dir C:\SilvaLiDARAirExercise\01_Sites\01_CapitolStateForestWA\01_LAZ --output-dir C:\SilvaLiDARAirExercise\03_Projects\cli_out\catalog --products terrain --buffer 25 --resolution 1 --report html
```

Result You can process any area, however large, tile by tile.

Check your understanding

1. Why does each tile read a buffer around it?
2. Why do very small tiles make a run slower?

13 EXERCISE 13
PICTURES AND VIDEOS



Figure 13.1 What you will make in this exercise.

Introduction

In this exercise you save pictures of the views and make a fly-through video of the stand.

You will learn to

- ✓ Save pictures of the views
- ✓ Make a spin video
- ✓ Make a fly-through video along a path

Prerequisites

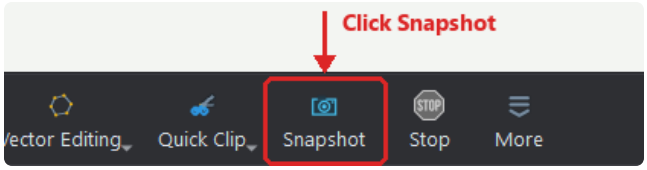
- Exercise 2 (and Exercise 7 for a virtual forest)

Overview of major steps

1. Save a snapshot
2. Make a spin video
3. Make a fly-through video

Procedure

Part 1: Snapshot



1. *Arrange* the view and *Click* **Snapshot**; *choose* the file and size.

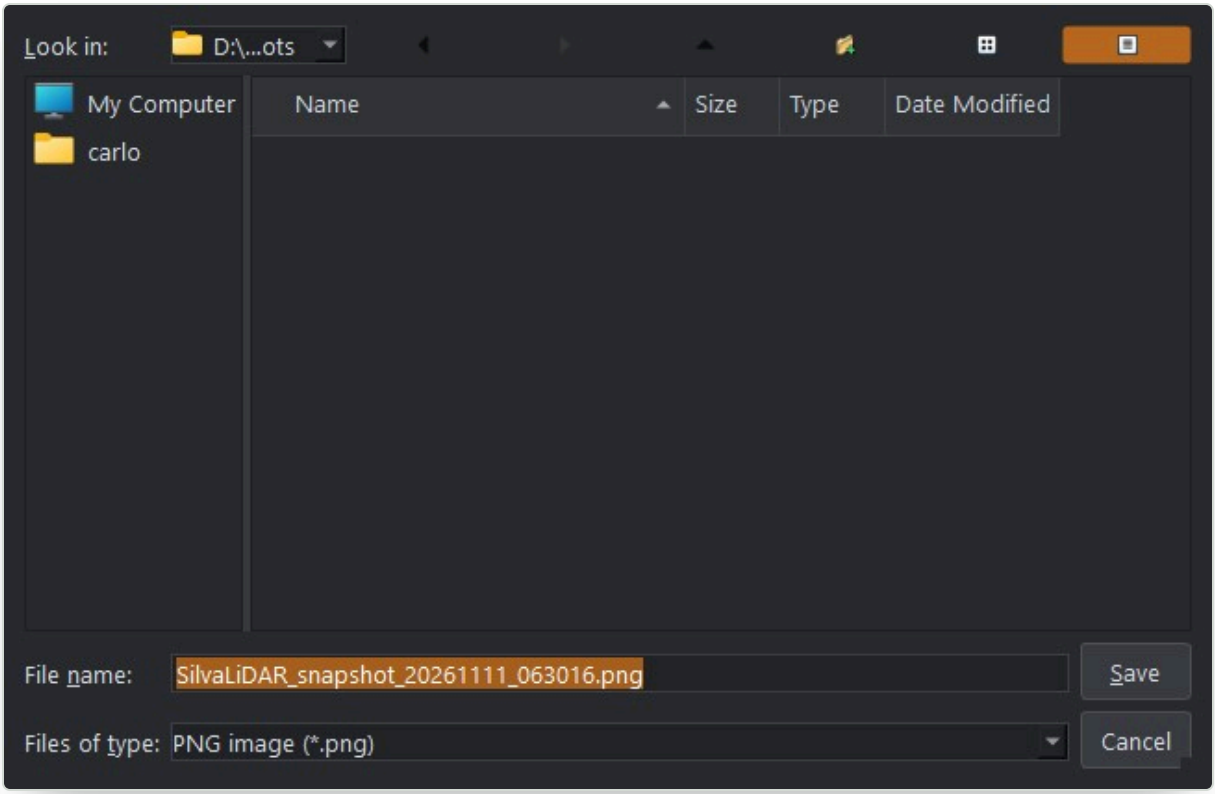


Figure 13.2 Snapshot.

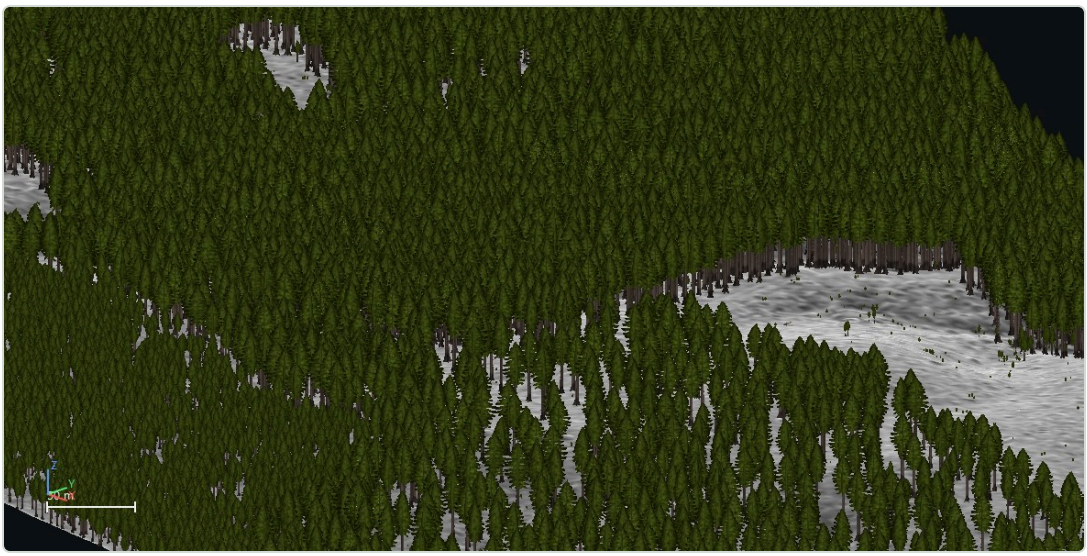
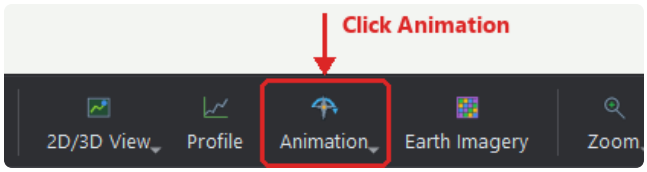


Figure 13.3 Fly-throughs over a virtual forest make striking videos.

Part 2: Spin



1. *Click* **Animation** › **Spin…**.
2. *Set* the time per turn, the number of turns and the view angle; *Click* **Start** to preview and **Export MP4** to save.

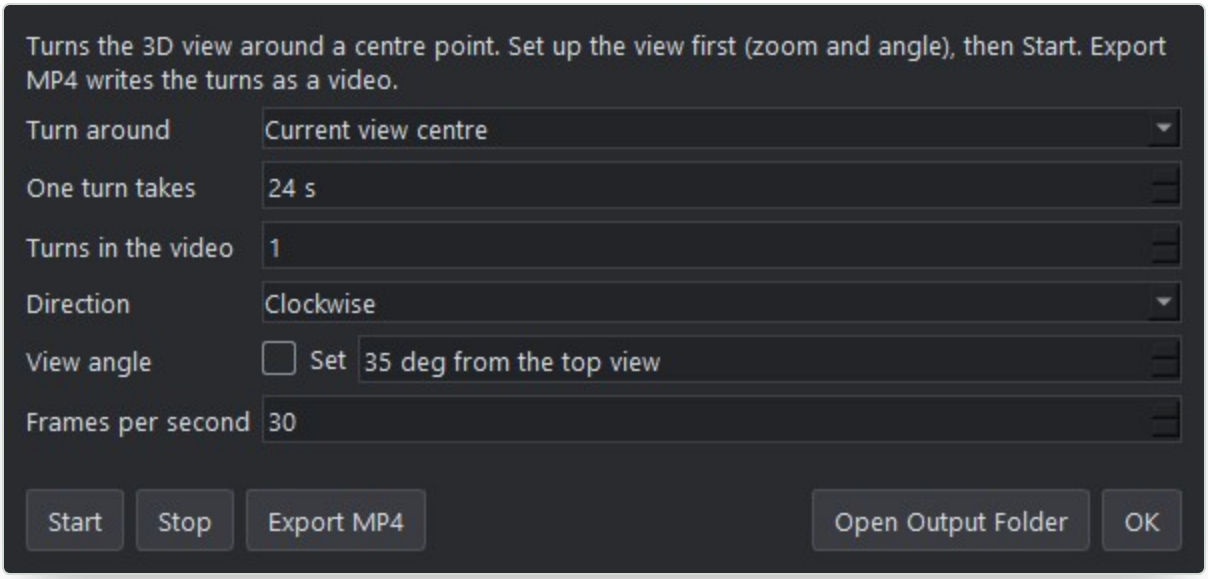


Figure 13.4 Spin.

Part 3: Flight Through

1. *Click* **Animation** › **Flight Through…**.
2. *Click* **Draw on 2D map** and *click* the path; *double-click* to finish.
3. *Drag* the points of the profile to set the camera height, then **Preview Flight** and **Export**.

> **Tip** SilvaLiDAR Air offers to download FFmpeg the first time you export a video.

Result You can make pictures and videos of the data for reports and presentations.

Did you know? A fly-through video always has every frame; only the preview skips frames to keep its timing on a large cloud.

Check your understanding

1. Which camera height would you choose for a flight above the canopy?
2. When is a spin better than a fly-through?

14 EXERCISE 14
SilvaAI AND THE COMMAND LINE

SilvaLiDAR Air 0.1.8.80

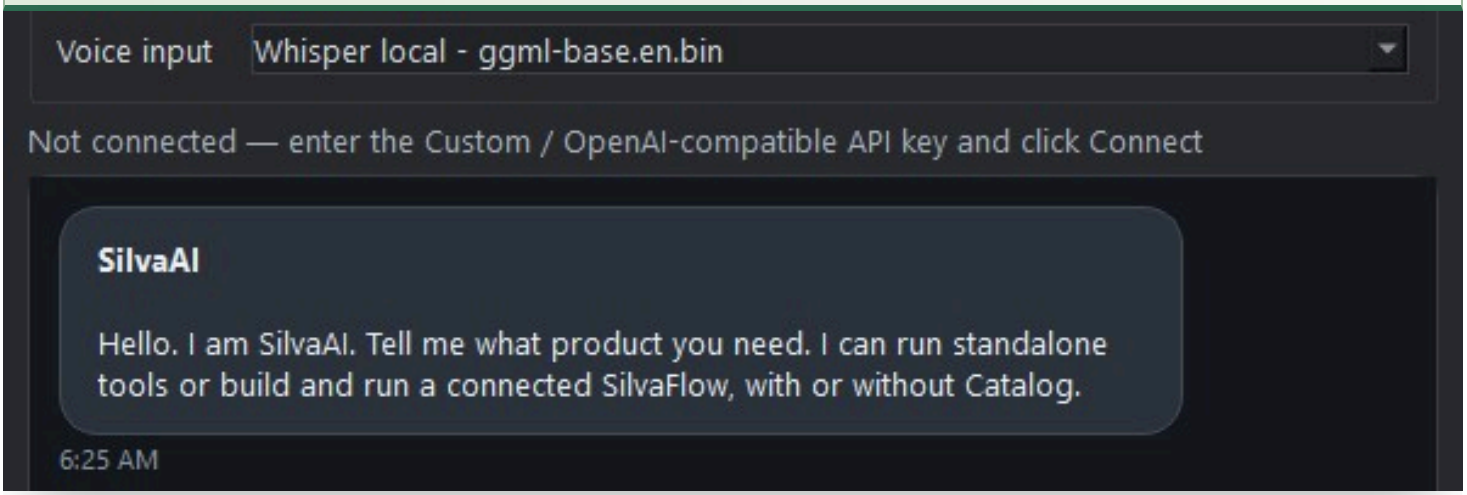


Figure 14.1 What you will make in this exercise.

Introduction

In this exercise you ask the assistant to build and run a workflow, and run a tool from the command line.

You will learn to

- ✓ Connect SilvaAI to a provider
- ✓ Ask questions and run workflows in plain language
- ✓ Run tools from scripts

Prerequisites

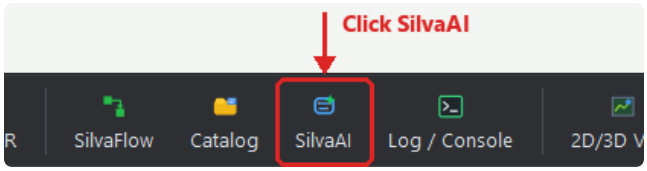
- Exercise 2
- For SilvaAI: a local model (Ollama) or your own key for a cloud provider

Overview of major steps

1. Connect SilvaAI
2. Ask a question and run a workflow
3. Run a tool from the command line

Procedure

Part 1: SilvaAI



1. *Click* **SilvaAI** and *connect* a provider (Local models, OpenAI, Anthropic, Gemini or a custom endpoint).
2. *Ask*: “Which CHM method should I use for a dense conifer forest?”
3. *Ask*: “Run ground filtering, DTM and CHM with Catalog.” SilvaAI builds the workflow, shows it and runs it.

Important Your messages and a summary of the project are sent to the provider you choose. Use a local model for data you may not share.

Part 2: The command line

Command line

```
SilvaLiDARAirCLI.exe --tool chm --input C:\SilvaLiDARAirExercise\03_Projects\cli_out\normalized.laz --output C:\SilvaLiDARAirExercise\03_Projects\cli_out\chm.tif --method pitfree --resolution 0.5
```

Command line

```
SilvaLiDARAirCLI.exe --tool trees --method silva2016 --input C:\SilvaLiDARAirExercise\03_Projects\cli_out\normalized.laz --output C:\SilvaLiDARAirExercise\03_Projects\cli_out\trees.laz --metrics-csv C:\SilvaLiDARAirExercise\03_Projects\cli_out\trees.csv
```

3. Your own metrics, for every plot: `SilvaLiDARAirCLI.exe --tool cloud-metrics --input-dir C:\SilvaLiDARAirExercise\01_Sites\01_CapitolStateForestWA\01_LAZ --shape C:\SilvaLiDARAirExercise\01_Sites\01_CapitolStateForestWA\02_SHP\plots_poly.shp --output-dir C:\SilvaLiDARAirExercise\03_Projects\cli_out\plot_metrics --custom-metrics my_metrics.txt`, where **my_metrics.txt** holds one `name = equation` per line, as in the designer. Without `--shape`, one row per input file; `--tool grid-metrics` gives the same metrics for every grid cell.

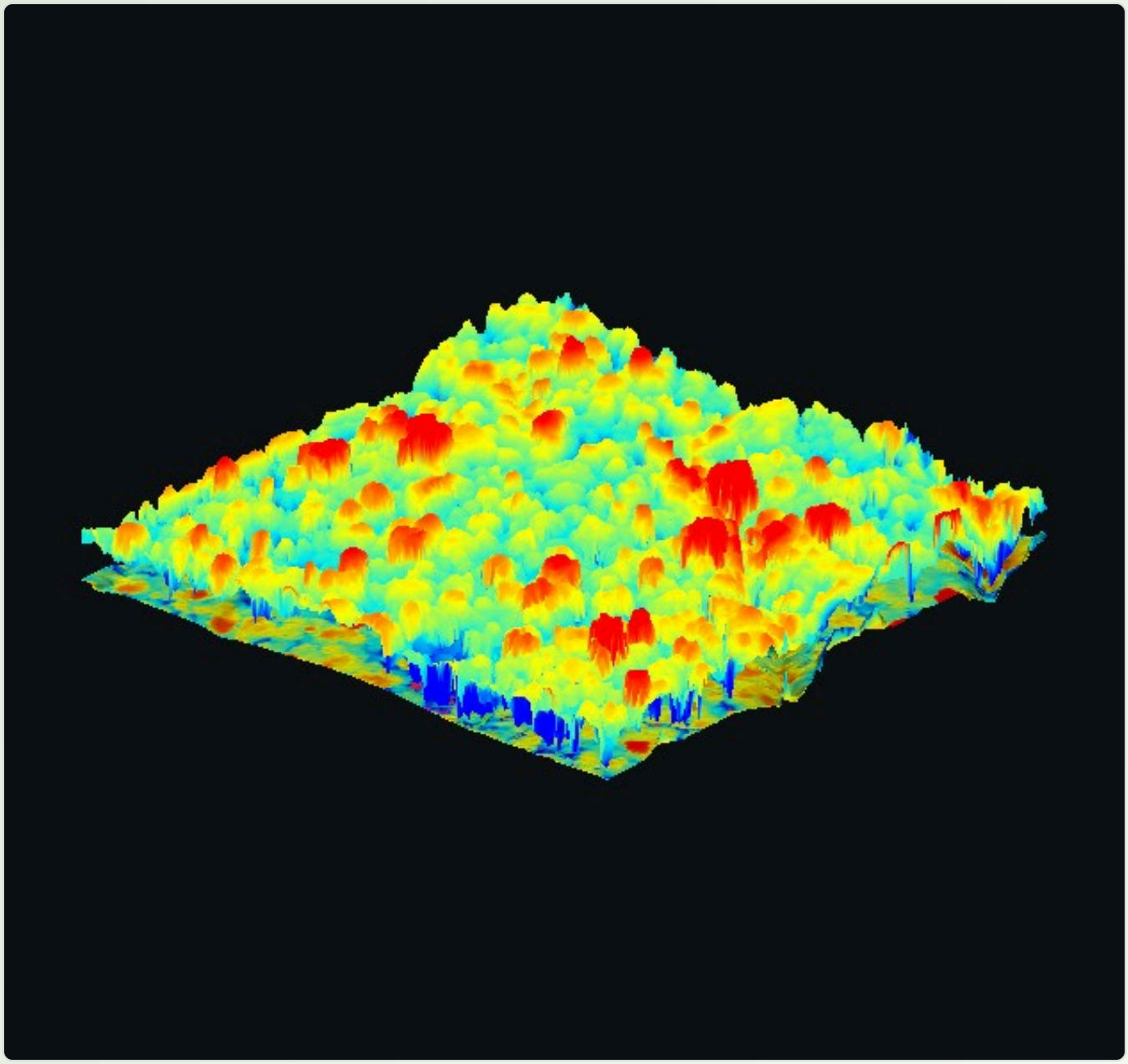
Tip Put such lines in a .bat file to process many files the same way.

Result You can drive SilvaLiDAR Air by asking in plain language, or from scripts.

Did you know? A request that names tools (“run Ground Filtering, DTM and CHM with Catalog”) is run; a question that starts with how, what, why or which is answered.

Check your understanding

1. When should you use a local model instead of a cloud provider?
2. How would you process 50 files the same way from the command line?



PART 4

Demonstrations

What SilvaLiDAR Air does with other data: the same plot scanned from a drone, on foot and from tripods, canopy gaps in the Amazon, and an AI model that learns point classes. The pages show the steps and the results. The scans of Demonstration A are not distributed; the exercise data hold the sites of Demonstrations B and C, so you can repeat them.

DEMONSTRATION A

A One plot from a drone, a mobile and a terrestrial scanner

Introduction

This demonstration shows the same 60 m of a pine plot in the Austin Cary Forest (University of Florida, Gainesville) scanned three ways: by a laser scanner on a drone (UAV), carried through the plot (MLS) and on a tripod (TLS). The mobile and terrestrial scans were collected by SilvaLab; the drone LiDAR was provided by Prof. Eben Broadbent, SPEC Lab (GatorEye), University of Florida. The data is not distributed with this guide.

Prerequisites

- Exercises 2 and 3 (views and profiles)

Overview of major steps

1. Register the scans with Align Point Clouds
2. Read the results
3. See the merged cloud
4. Compare the three scans

Procedure

Part 1: Register the scans

1. *Open* **Tools** › **Point Cloud** › **Align Point Clouds…**.
2. *Choose* the drone (UAV) cloud as the **reference** and *add* the mobile (MLS) and terrestrial (TLS) clouds as the clouds to align.
3. *Tick* **Also merge the reference and the aligned clouds into one file** and *Click* **Align**: a coarse match of terrain and canopy, then a fine point-to-plane match on the ground and stems.

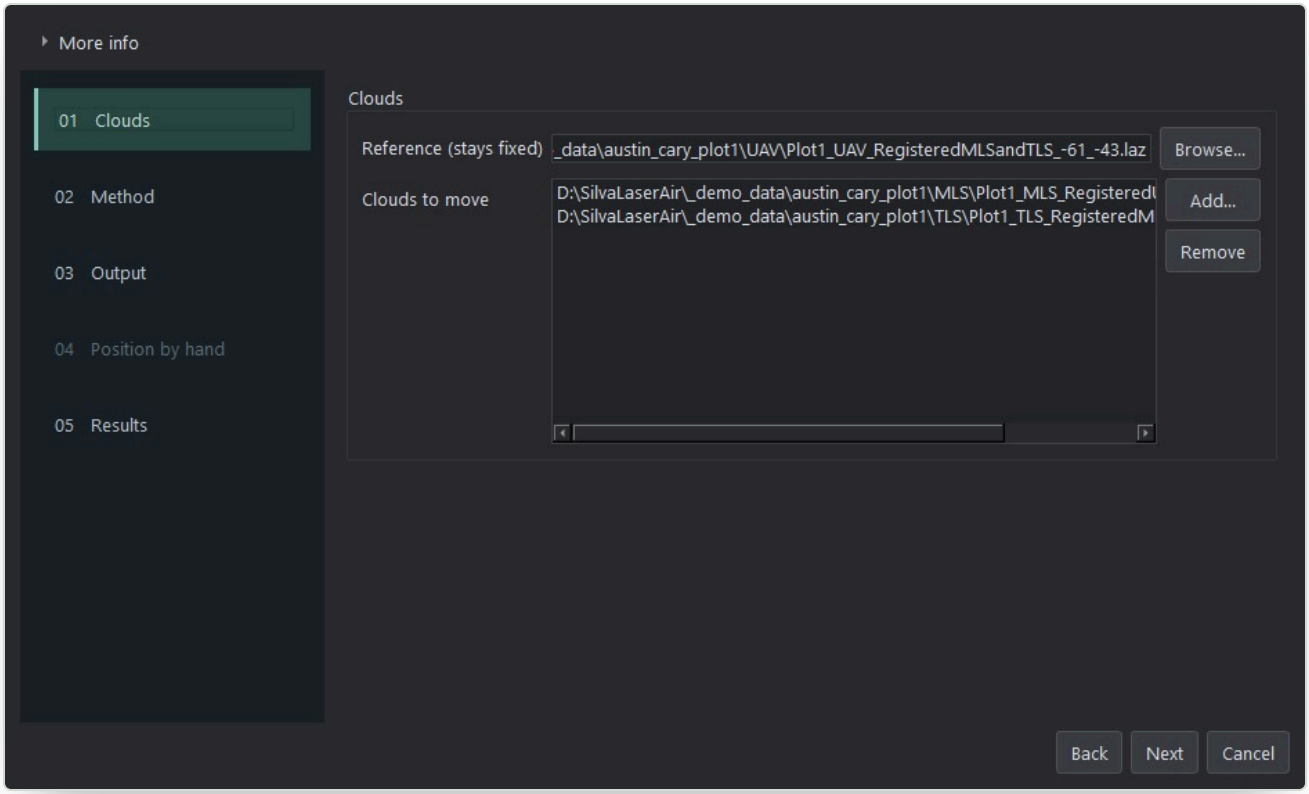


Figure A.1 Align Point Clouds: the drone cloud as the reference, the mobile and terrestrial clouds to align.

Part 2: The registration results

1. The results window has one tab per aligned cloud: the distance to the reference after each stage, a distance map and a cross-section.
2. Here the scans had been registered before, so the alignment confirms it: the mobile cloud ends a median 6 cm from the drone surface.

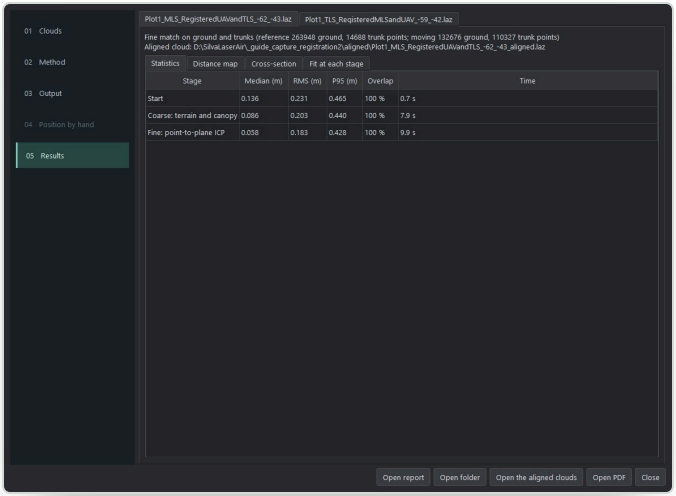


Figure A.2 The statistics: median and RMS distance to the reference after each stage.



Figure A.3 The distance map of the mobile cloud after alignment.

Part 3: The merged cloud

1. The merged file holds the three scans in one cloud; each point keeps the number of its cloud in Point Source ID.
2. *Open* it: the drone gives the crowns, the mobile and terrestrial scanners the stems and the understory.

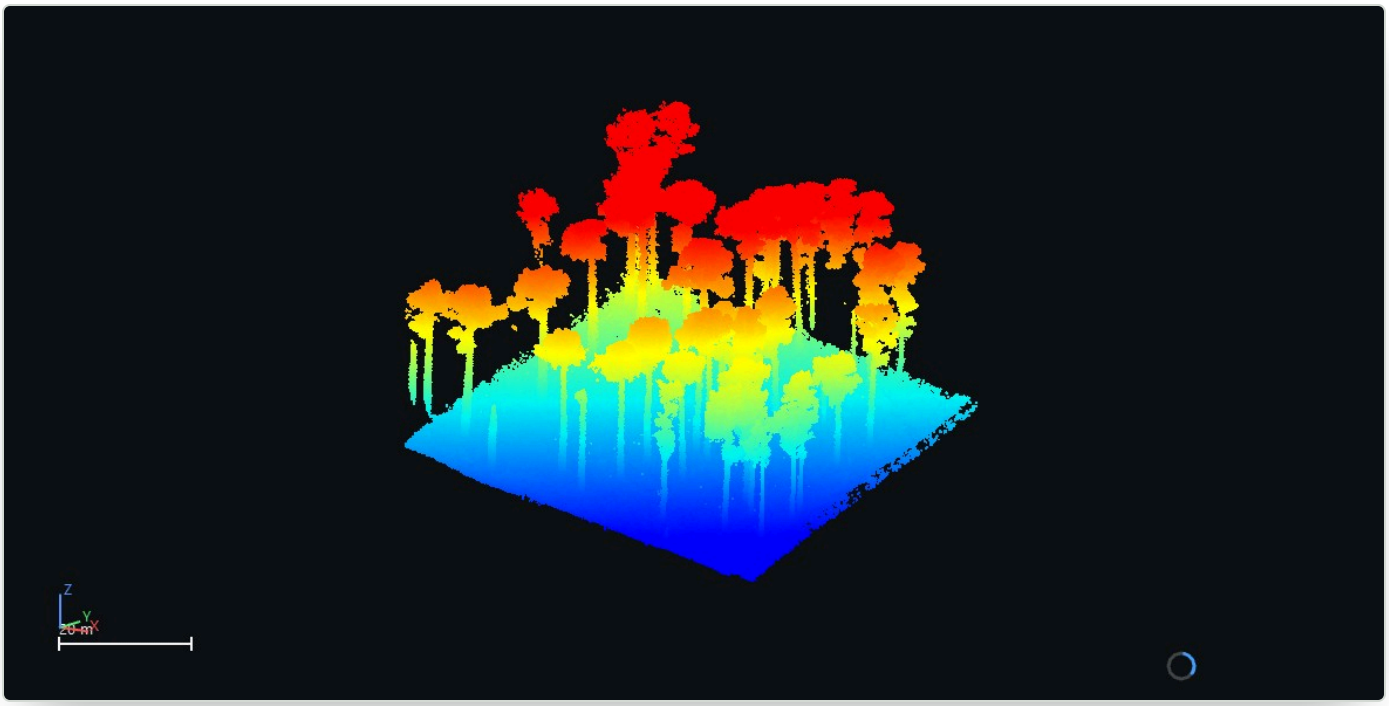


Figure A.4 The merged cloud, coloured by elevation.

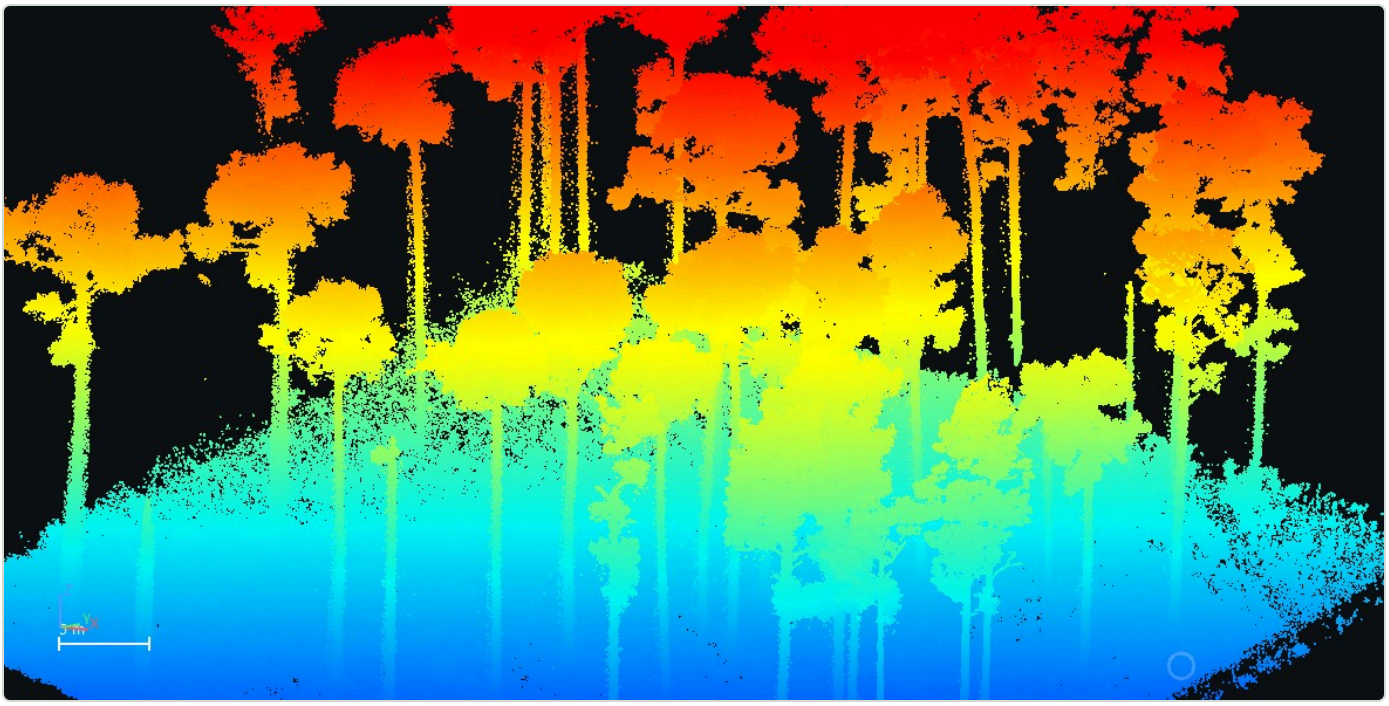


Figure A.5 Close up.

Part 4: The drone (UAV)

1. *Open* the UAV cloud and *colour* it by elevation.
2. *Look* at it from the side and close up, then *draw* a profile across the plot.

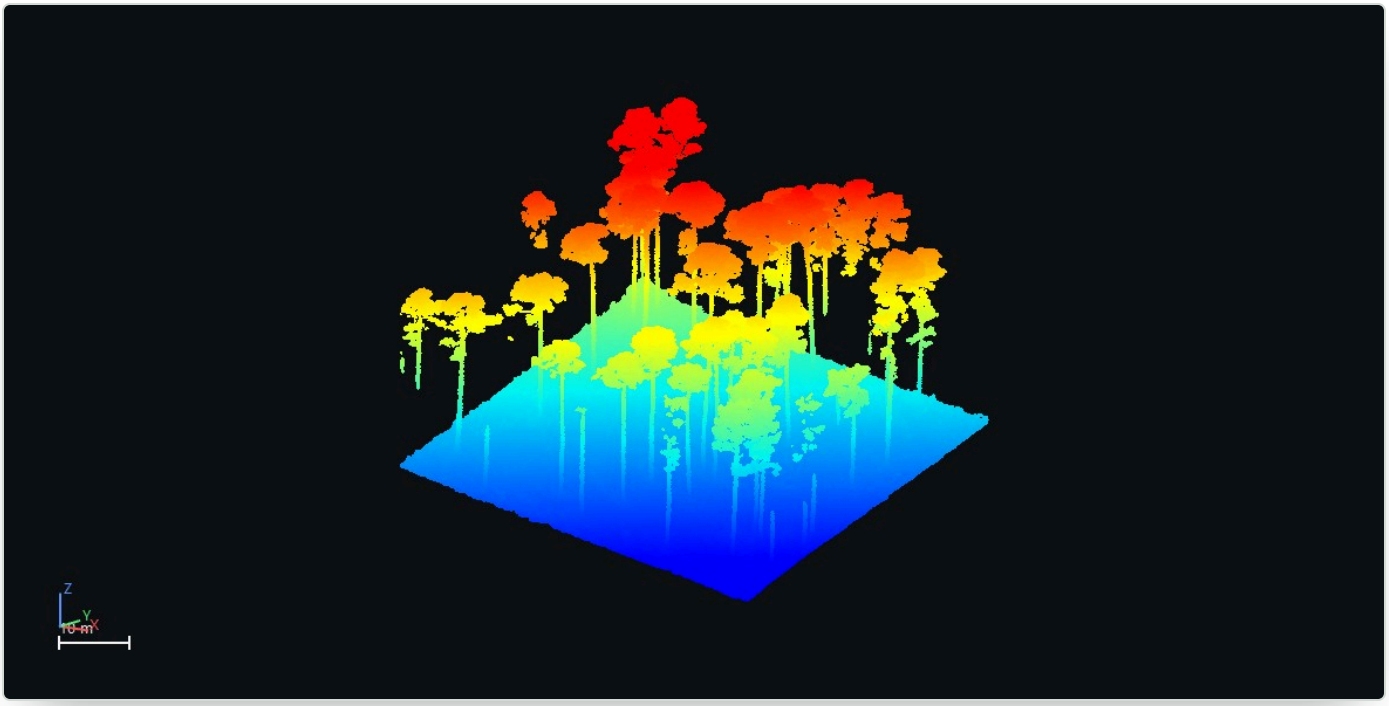


Figure A.6 From the drone (UAV), coloured by elevation: about 3 million points over the 60 m.

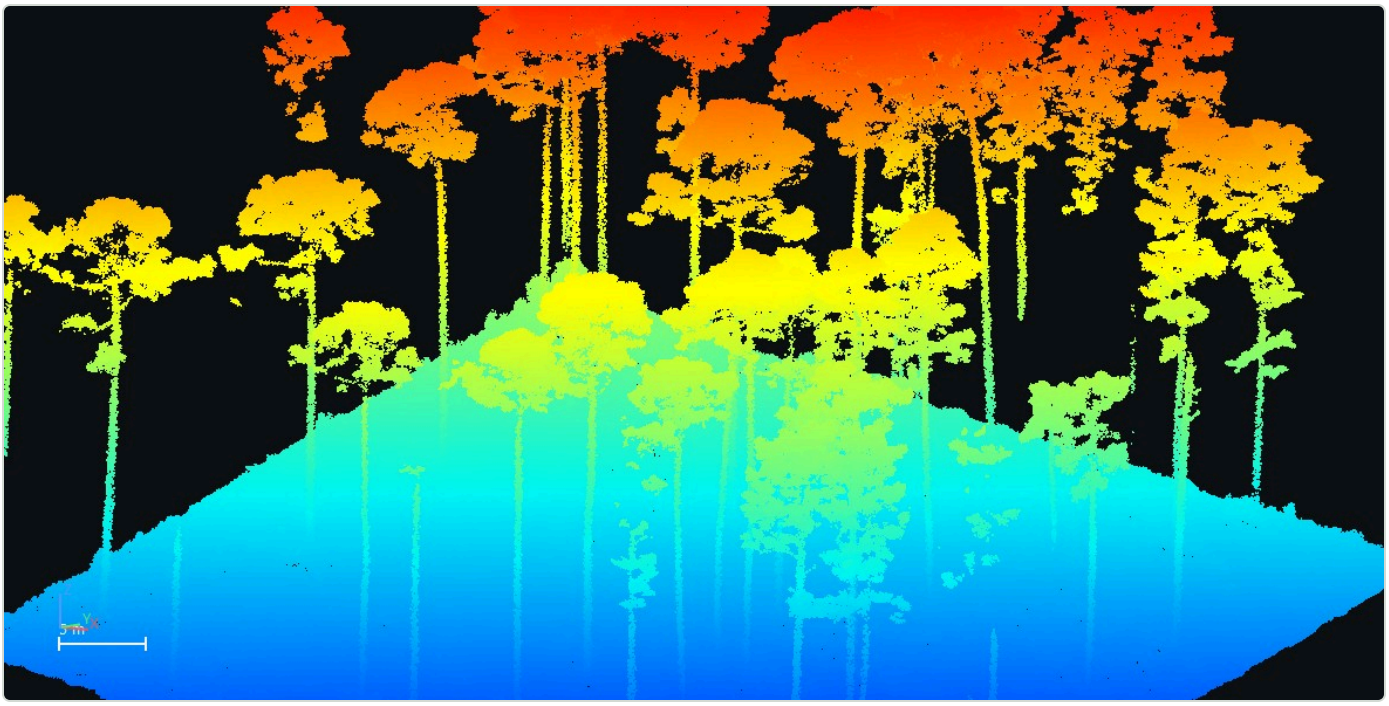


Figure A.7 Close up: crowns, stems and the ground under them.

Part 5: The mobile scanner (MLS)

1. *Open* the MLS cloud: the same area, walked through with the scanner.

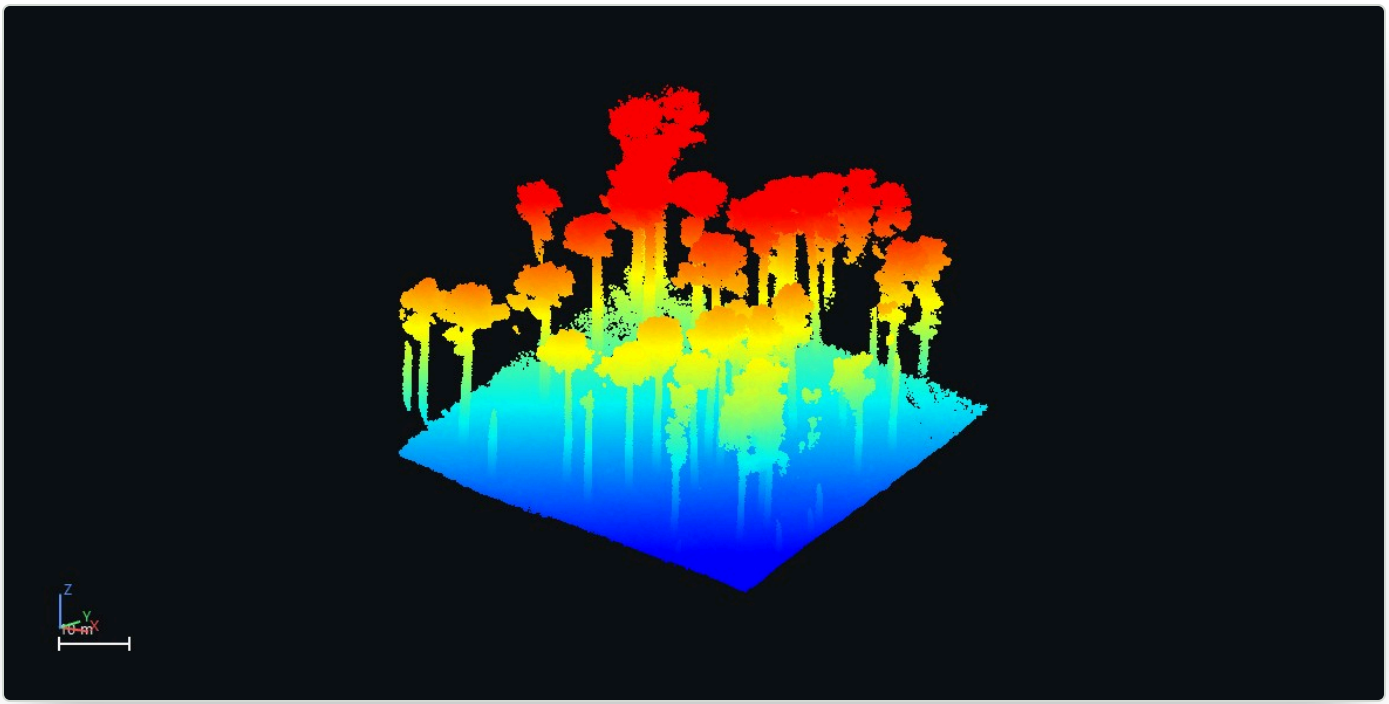


Figure A.8 From the mobile scanner (MLS): about 60 million points over the same area.

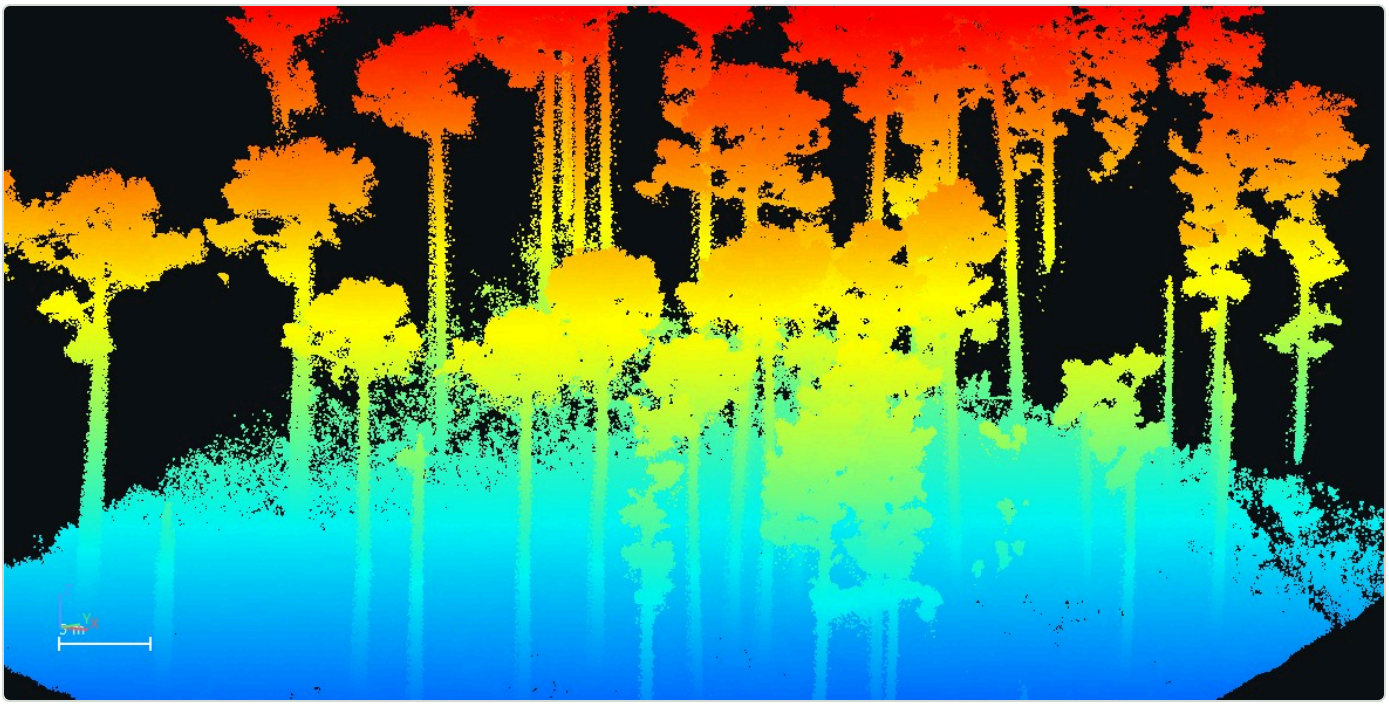


Figure A.9 Close up: the stems and the understorey from the walking scanner.

Part 6: The terrestrial scanner (TLS)

1. *Open* the TLS cloud: scans from tripods inside the plot, merged.

> **Note** Align Point Clouds (Tools › Point Cloud) brings clouds like these onto one another when they are not registered yet.

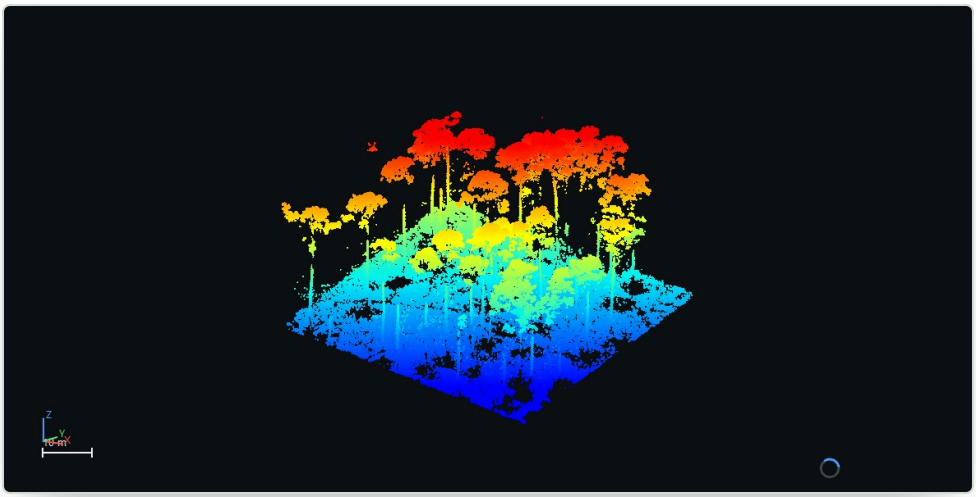


Figure A.10 From the terrestrial scanner (TLS), opened as a streamed cloud: too many points to hold in memory at once.

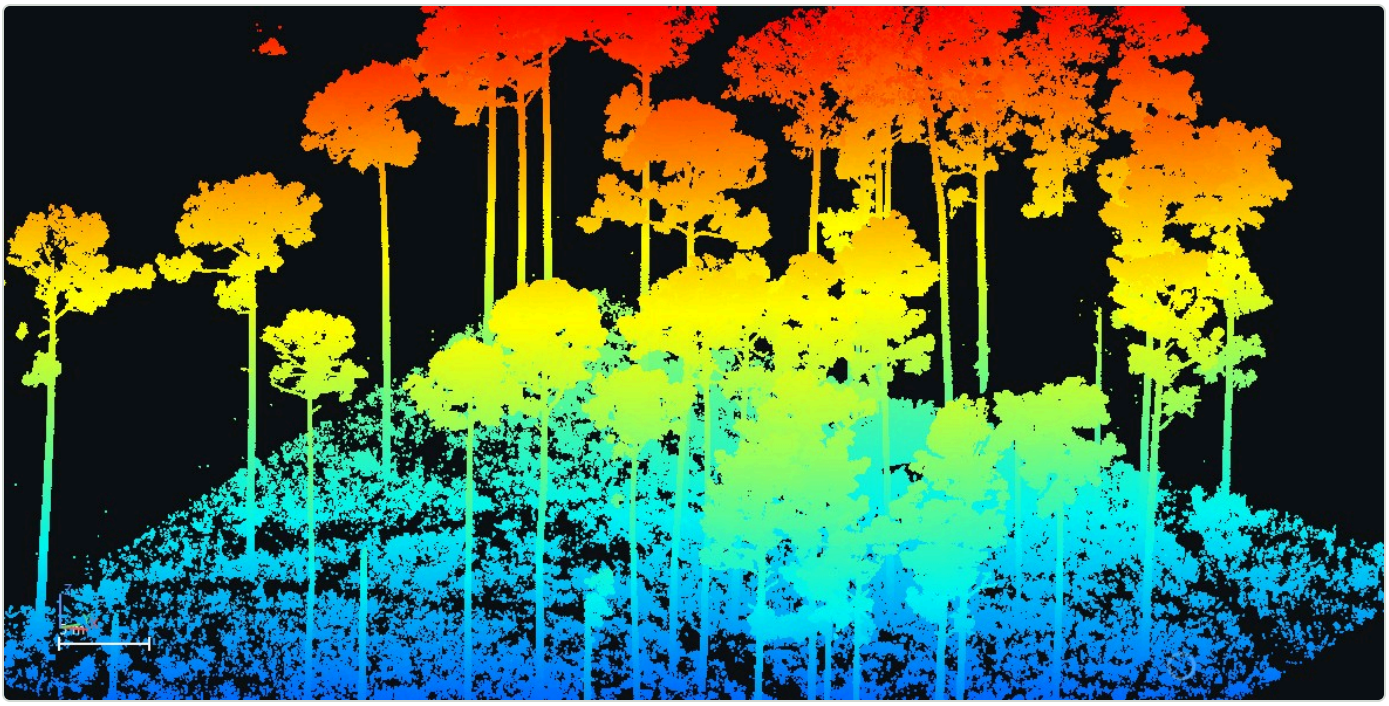


Figure A.11 Close up: stems and crowns from the scanner positions inside the plot.

Result The three scanners record the same trees with very different numbers of points: a few million from the drone, tens of millions from the mobile and terrestrial scanners.

B DEMONSTRATION B
CANOPY GAPS IN A TROPICAL FOREST

Introduction

This demonstration maps canopy gaps in 400 m × 400 m of tropical forest at Fazenda Cauaxi, in the eastern Amazon (Pará, Brazil), from airborne LiDAR flown in 2014. The exercise data hold a tile of the same forest, **02_AmazonBrazil\01_LAZ\CAUL7780C9583.laz** (EPSG:31982 is in its header): repeat these steps on it.

Prerequisites

- Exercises 5 and 6 (terrain, CHM and canopy gaps)

Overview of major steps

1. Ground, DTM, normalization and CHM
2. Canopy Gap
3. Look at the gaps on the map, in 3D and in a profile

Procedure

Part 1: The canopy

1. *Run* **Ground Filtering**, **DTM**, **Height Normalization** and **CHM** with their defaults.

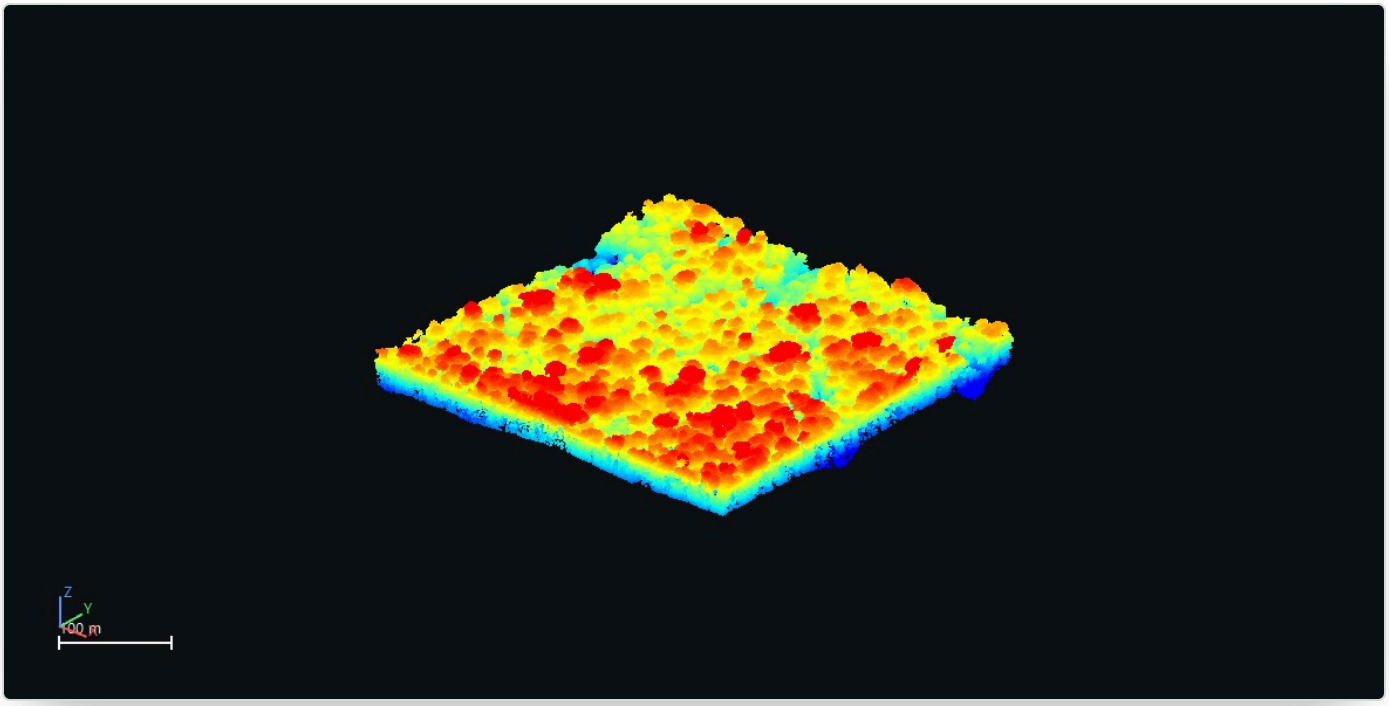


Figure B.1 The forest coloured by elevation.

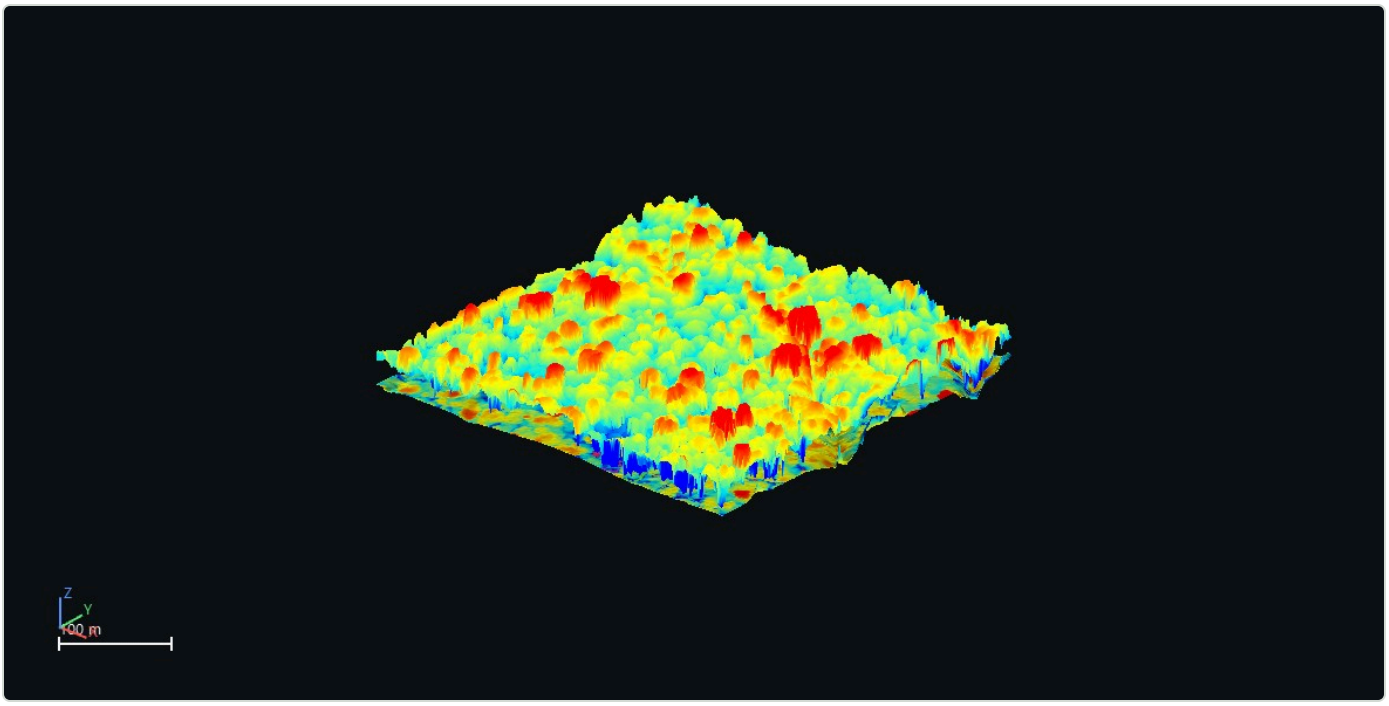


Figure B.2 The canopy height model in 3D.

Part 2: The gaps

1. *Run* **Tools** › **Canopy** › **Canopy Gap** with its defaults (openings below 10 m, from 1 m²).
2. *Draw* a profile across a gap.

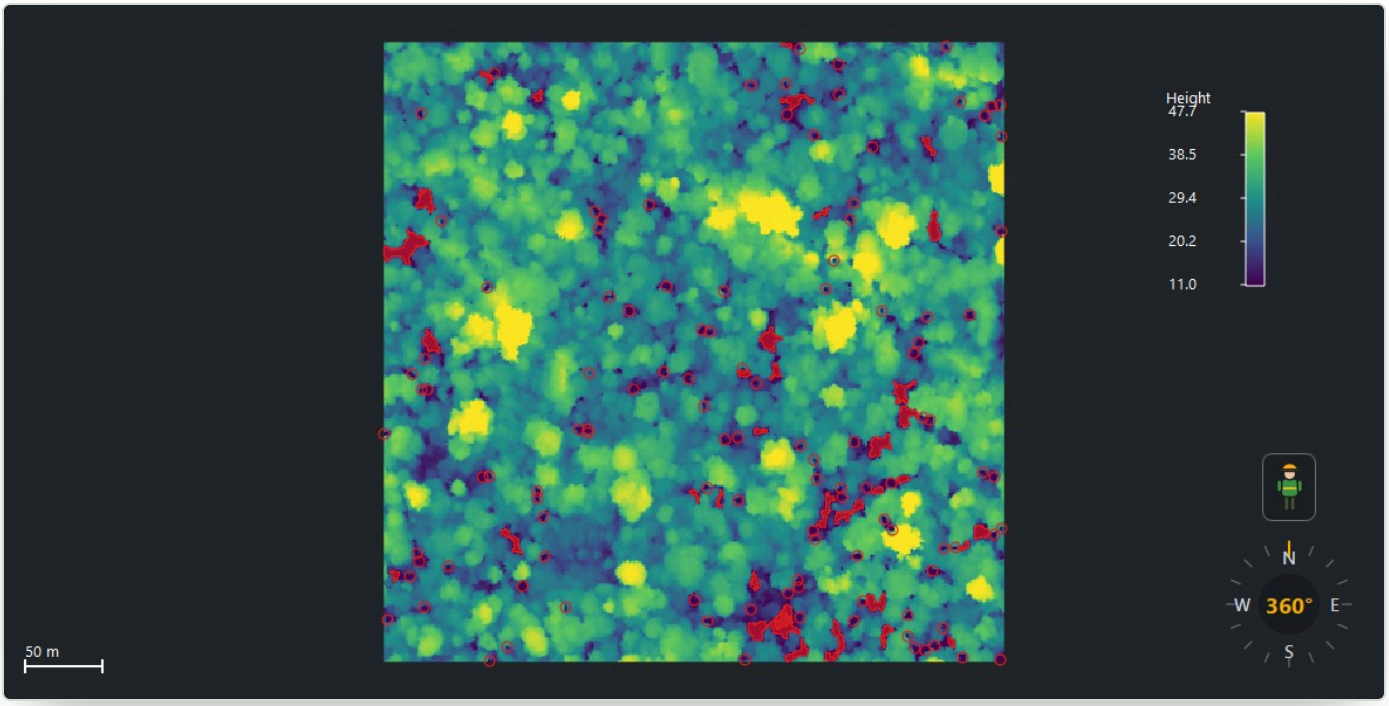


Figure B.3 The gaps over the CHM.

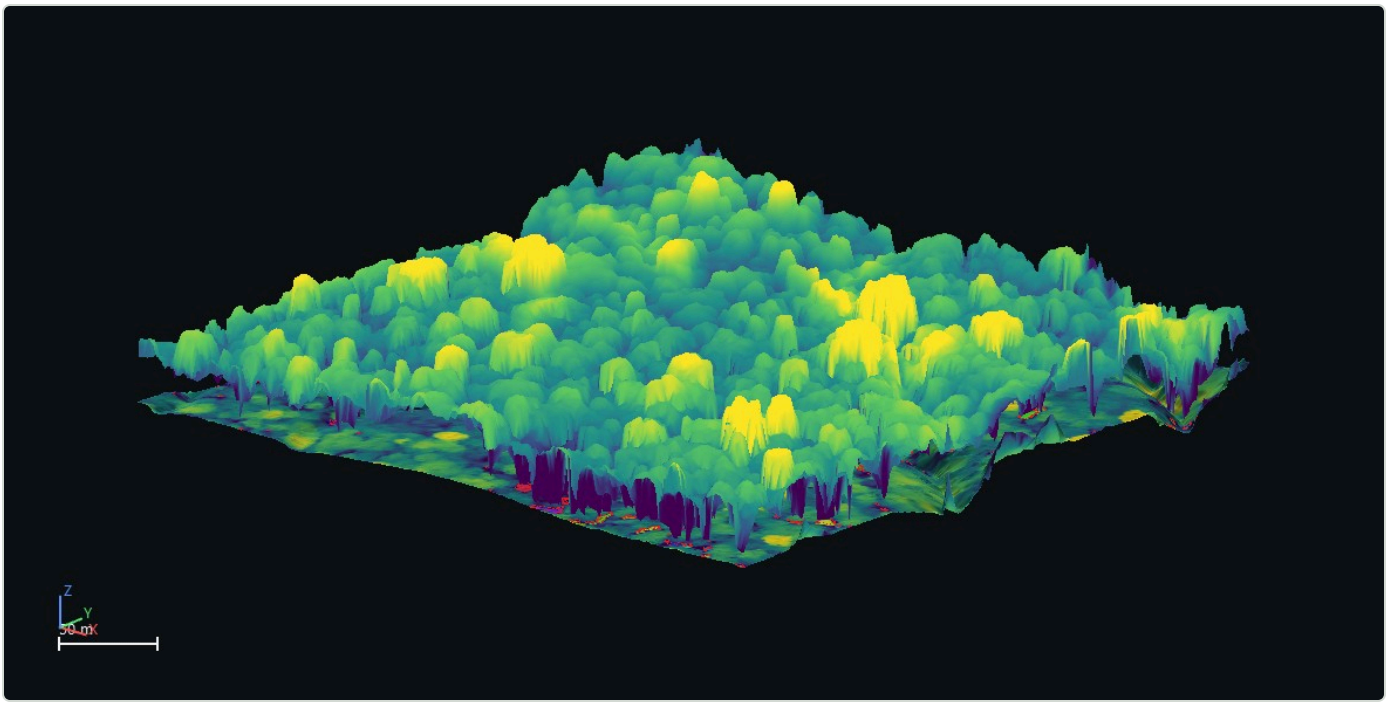


Figure B.4 The gaps draped on the terrain.

Result Canopy Gap finds the openings of a tall, uneven tropical canopy: tree falls, logging gaps and roads.

C DEMONSTRATION C

AI CLASSIFICATION: LABEL, TRAIN AND APPLY

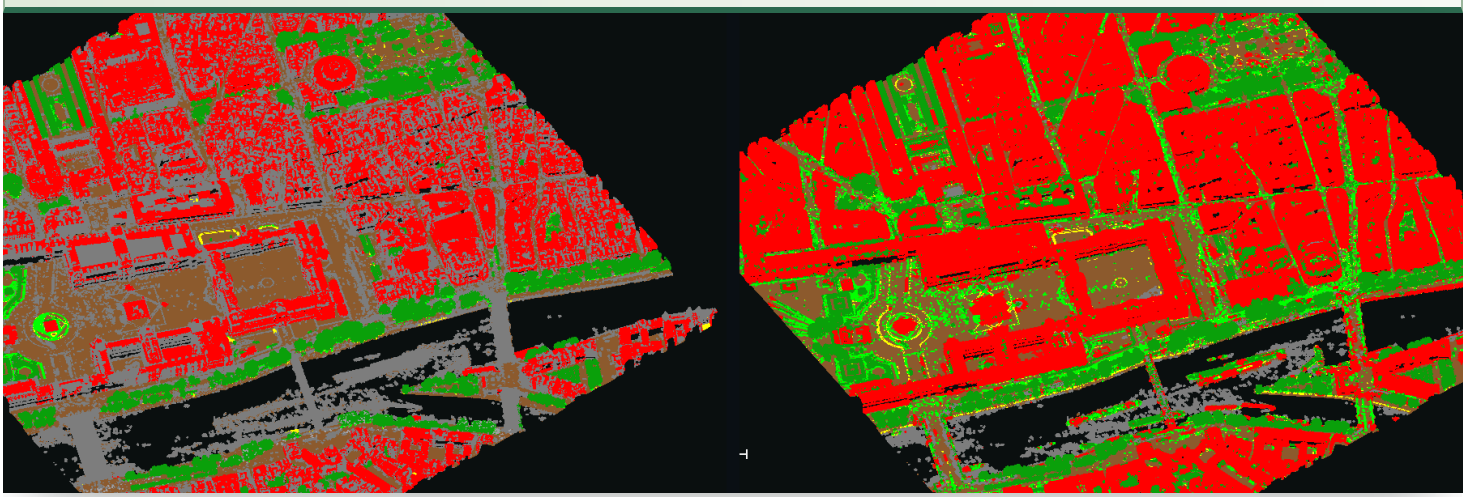


Figure C.1 What you will make in this exercise.

Introduction

This demonstration shows how to teach SilvaLiDAR Air your own point classes: you label points, train a model with a Random Forest or a deep network (PointNet, PointNet++ or PointNeXt), read its accuracy, and classify another cloud with it. The pictures use two free tiles of the French national LiDAR (IGN LiDAR HD) over Paris: a park to learn from and the city centre to classify. Both tiles are in the exercise data, **03_ParisFrance\01_LAZ**, so you can repeat these steps.

You will learn to

- ✓ Label points in 2D and 3D
- ✓ Train a Random Forest, PointNet, PointNet++ or PointNeXt
- ✓ Judge a model with IoU, F1, omission, commission and disagreement
- ✓ Classify new clouds and fine-tune a model

Prerequisites

- Exercise 2
- The two Paris tiles of the exercise data (IGN LiDAR HD, Etalab 2.0 licence), already classified by IGN

Overview of major steps

1. Label points
2. Choose the clouds and the classes
3. Choose the features and the learner
4. Read the accuracy
5. Classify another cloud
6. Continue training a model (fine-tuning)

Procedure

Part 1: Label points

1. *Open* the cloud to label (it must be in memory: clip a large streamed collection first).
2. *Open* **Tools** › **Canopy** › **Classification**, *choose* **Label points** and *Click* **Next**. The cloud is coloured by class and the Label Points bar opens.

3. *Choose* the **Class** (or *type* any number and a name, such as **64 Car**), then a drawing tool: **Map polygon** or **Map box** on the 2D map, or **3D lasso** or **3D box** in the 3D scene. The 3D lasso follows the camera, so a slanted crown, a wall or a wire can be picked out.
4. Only the points shown get the class: *use* the display filters (classes, heights) to narrow a drawing, and **Only points of** to change only one class, for example only unclassified points. **Undo** takes back the last drawing.
5. *Click* **Save labelled cloud…**. Label several places with every class you want, the rare ones included.

> **Tip** Label a little of everything, in several places: a model learns from variety more than from quantity.

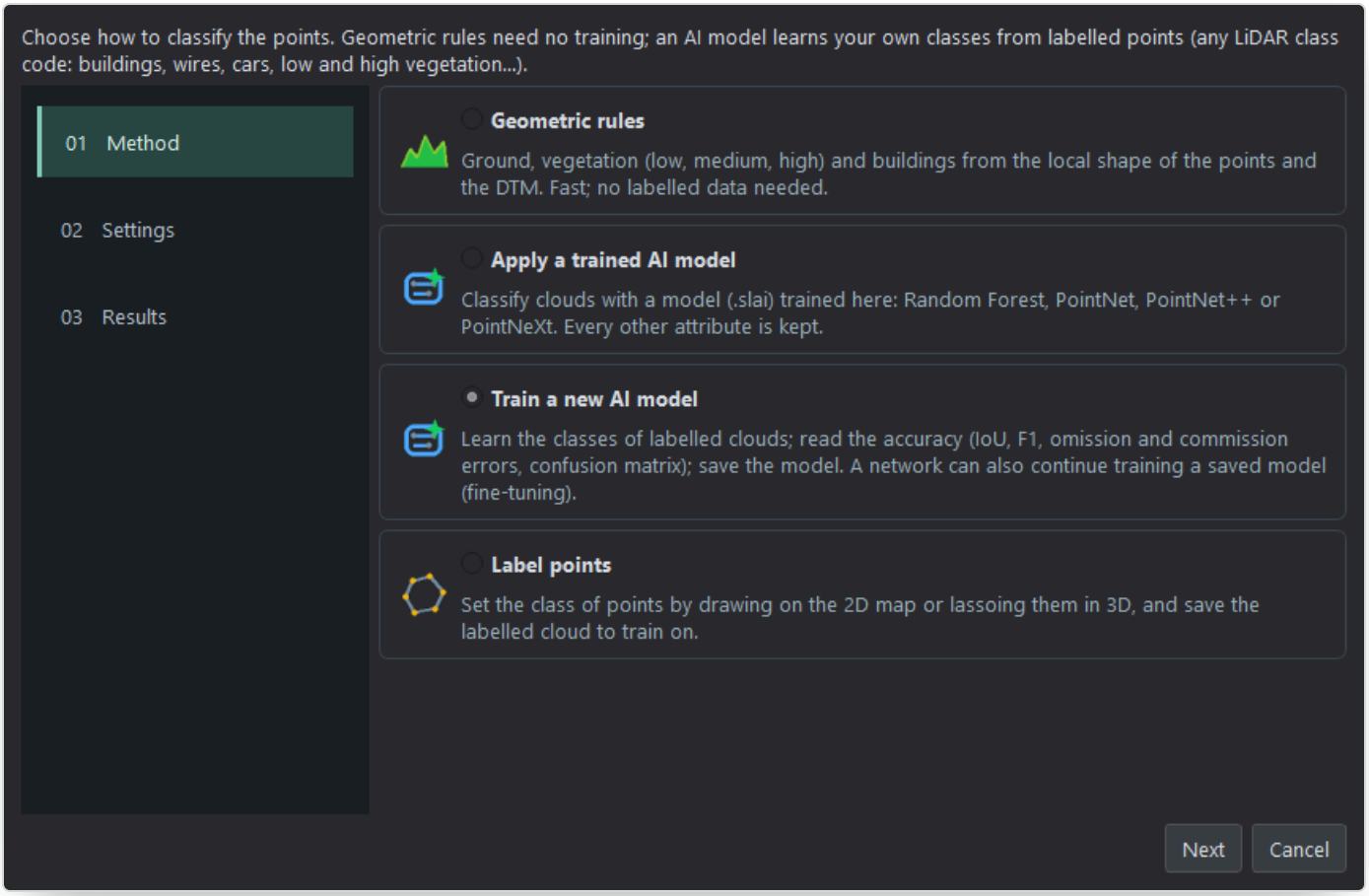


Figure C.2 The Classification panel: geometric rules and the AI methods in one place.

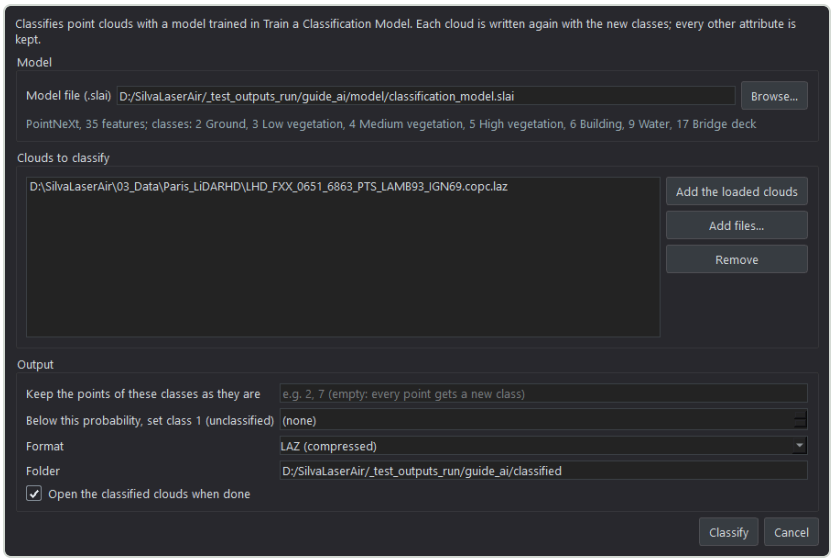


Figure C.3 Apply a Model: the model, the clouds and what to keep.

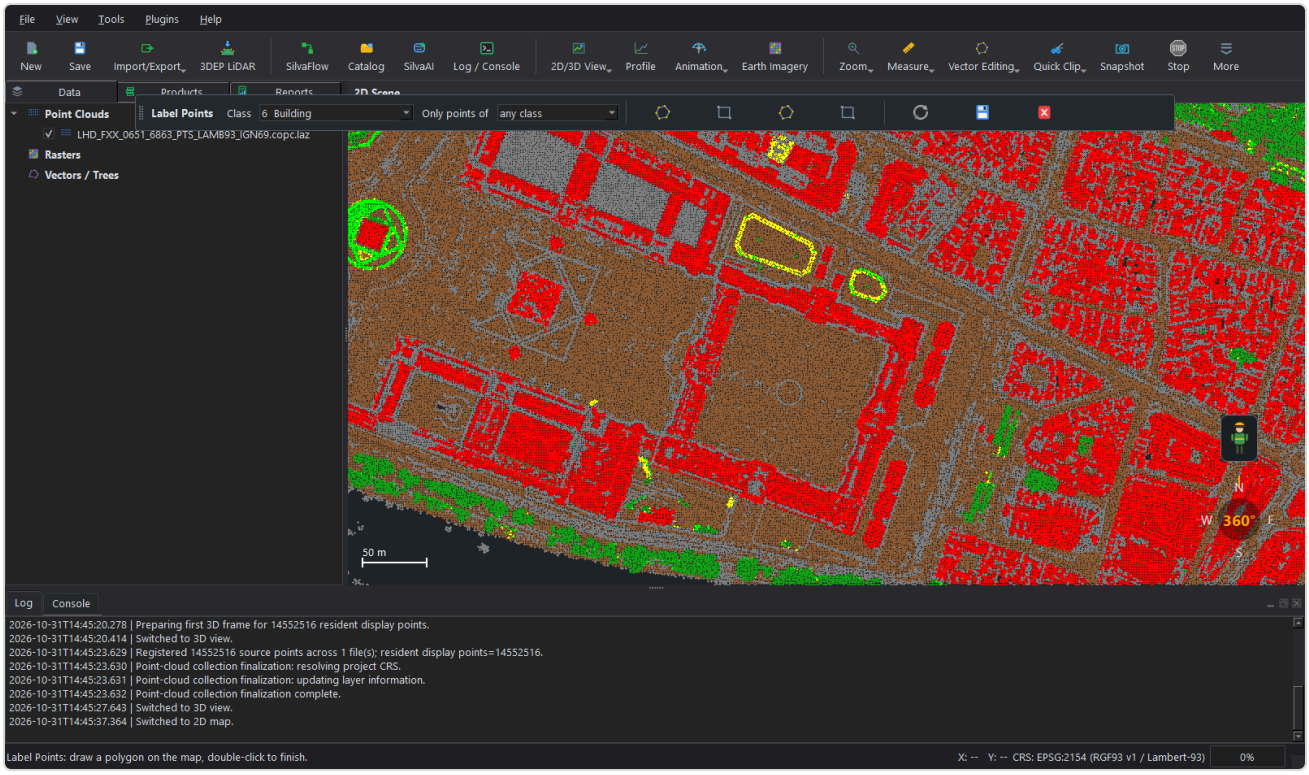


Figure C.4 The Label Points bar over the map, drawing a polygon.

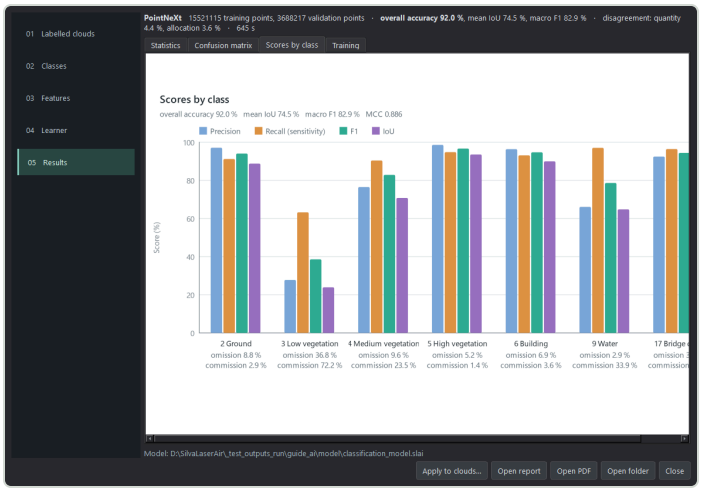


Figure C.5 Scores by class, with the omission and commission errors.

Part 2: The clouds and the classes

1. *Open* **Tools** › **Canopy** › **Classification**, *choose* **Train a new AI model** and *Click* **Next**. (The same panel holds the geometric rules and the other AI methods.)
2. **01 Labelled clouds**: *Click* **Add files…** (or **Add the loaded clouds**) and *choose* the labelled clouds; here the Bois de Boulogne tile.
3. **02 Classes**: every class found is listed with its number of points. *Untick* the classes the model should not learn (noise, unclassified points, classes with very few points).

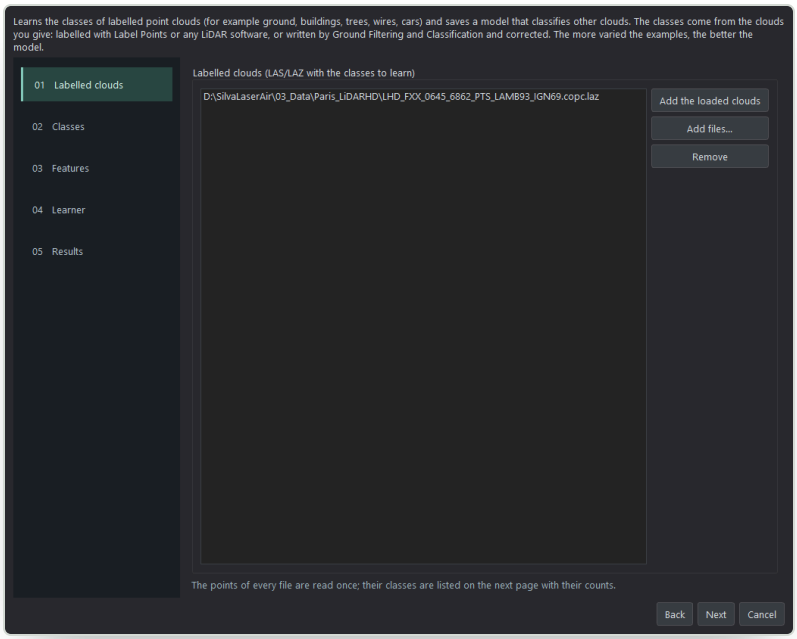


Figure C.6 01 Labelled clouds.

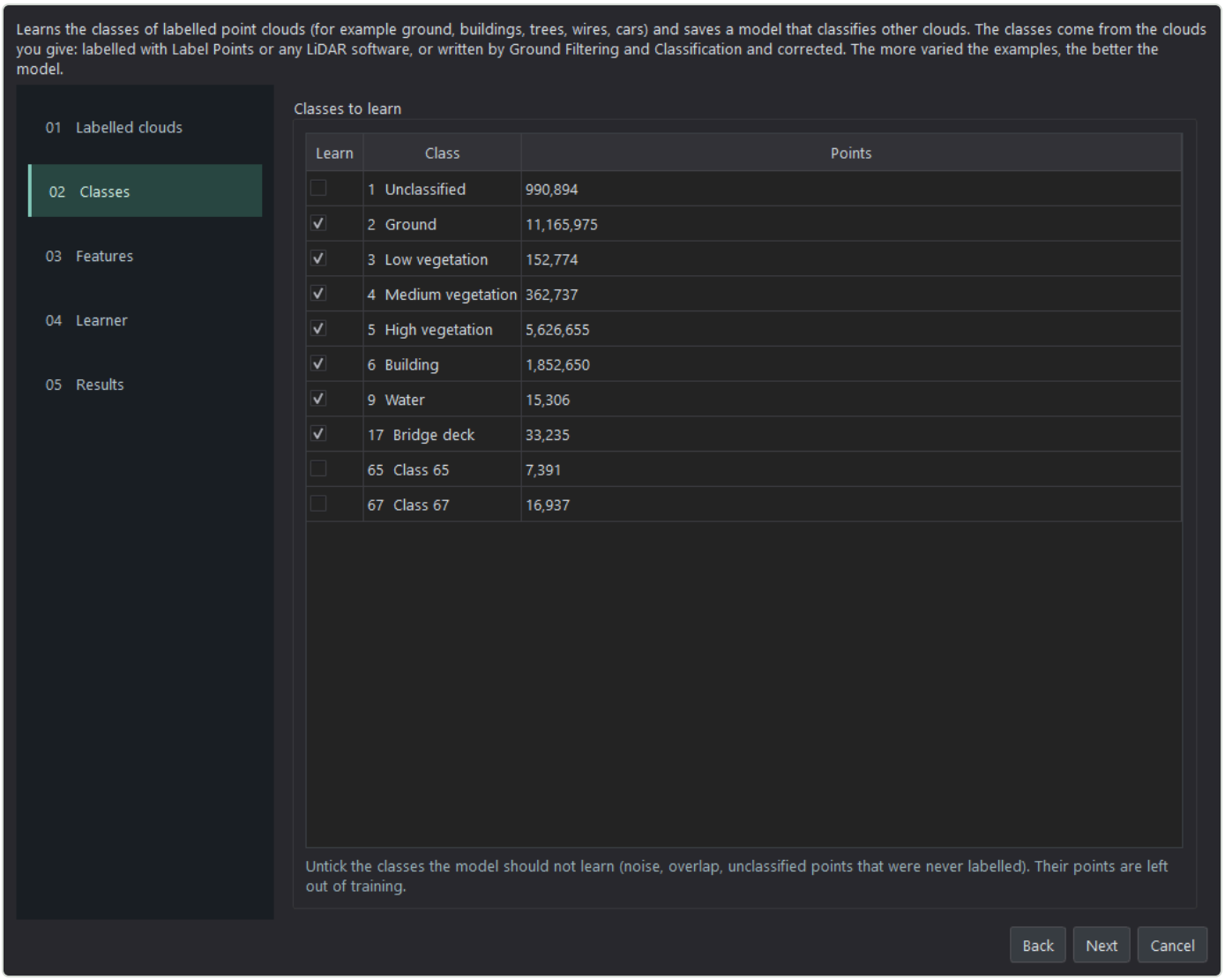


Figure C.7 02 Classes, with their points.

Part 3: Features and learner

1. **03 Features**: the shape of each point's neighbourhood at three sizes (0.5, 1 and 2 m by default), its height above the lowest points around, intensity and returns (and colour when every cloud has it).
2. **04 Learner**: **Random Forest** is fast and shows which features matter. **Deep network (PointNet-style)** looks at each point's nearest neighbours. **PointNet++** and **PointNeXt** learn from patches of about a thousand points and see the shape around each point: a roof edge, a crown, a wire span. PointNeXt adds residual blocks and a modern training recipe, and is usually the most accurate.
3. Part of the labelled points, in whole blocks, is held out to measure the accuracy on places the model has not seen. *Click* **Train**.

> **Note** Every learner is SilvaLiDAR Air's own code and trains on your computer's processor: no graphics card or internet connection is needed.

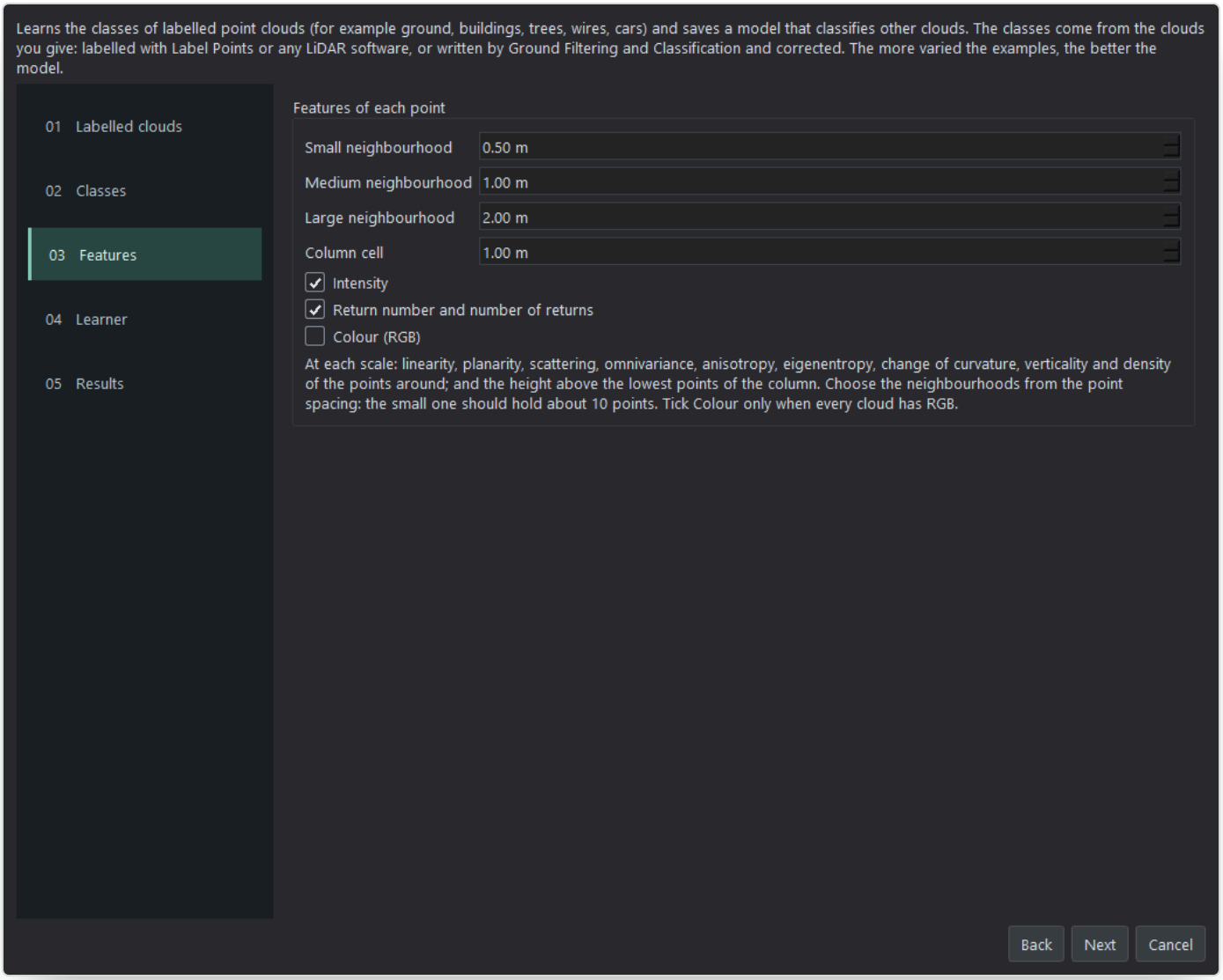


Figure C.8 03 Features.

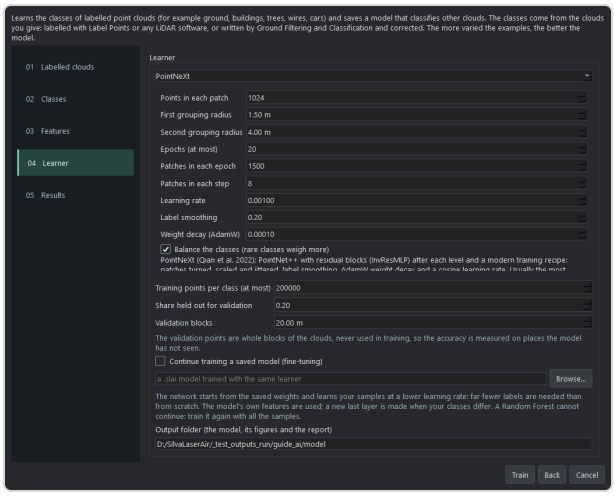


Figure C.9 04 Learner: PointNeXt and its settings.

Part 4: Read the accuracy

1. The **Statistics** tab gives, on the held-out blocks, the **overall accuracy**, the **mean IoU**, **macro F1** and **balanced accuracy** (which weigh small classes as much as large ones), the **MCC**, and the **quantity** and **allocation disagreement**; and for each class **precision** (user's accuracy), **recall** or sensitivity (producer's accuracy), **F1**, **IoU**, **omission** and **commission** errors and **specificity**.
2. The **Confusion matrix** shows where each class's points went; **Scores by class** draws the class scores; the **Training** curve shows the accuracy after each epoch (the forest shows the **Feature importance** instead).
3. **Open report** and **Open PDF** give the model report; the model itself is **classification_model.slai**.

> **Tip** Kappa is not reported: its random-agreement baseline has no meaning for a map. Quantity and allocation disagreement tell whether the errors come from wrong class totals or from points in the wrong places.

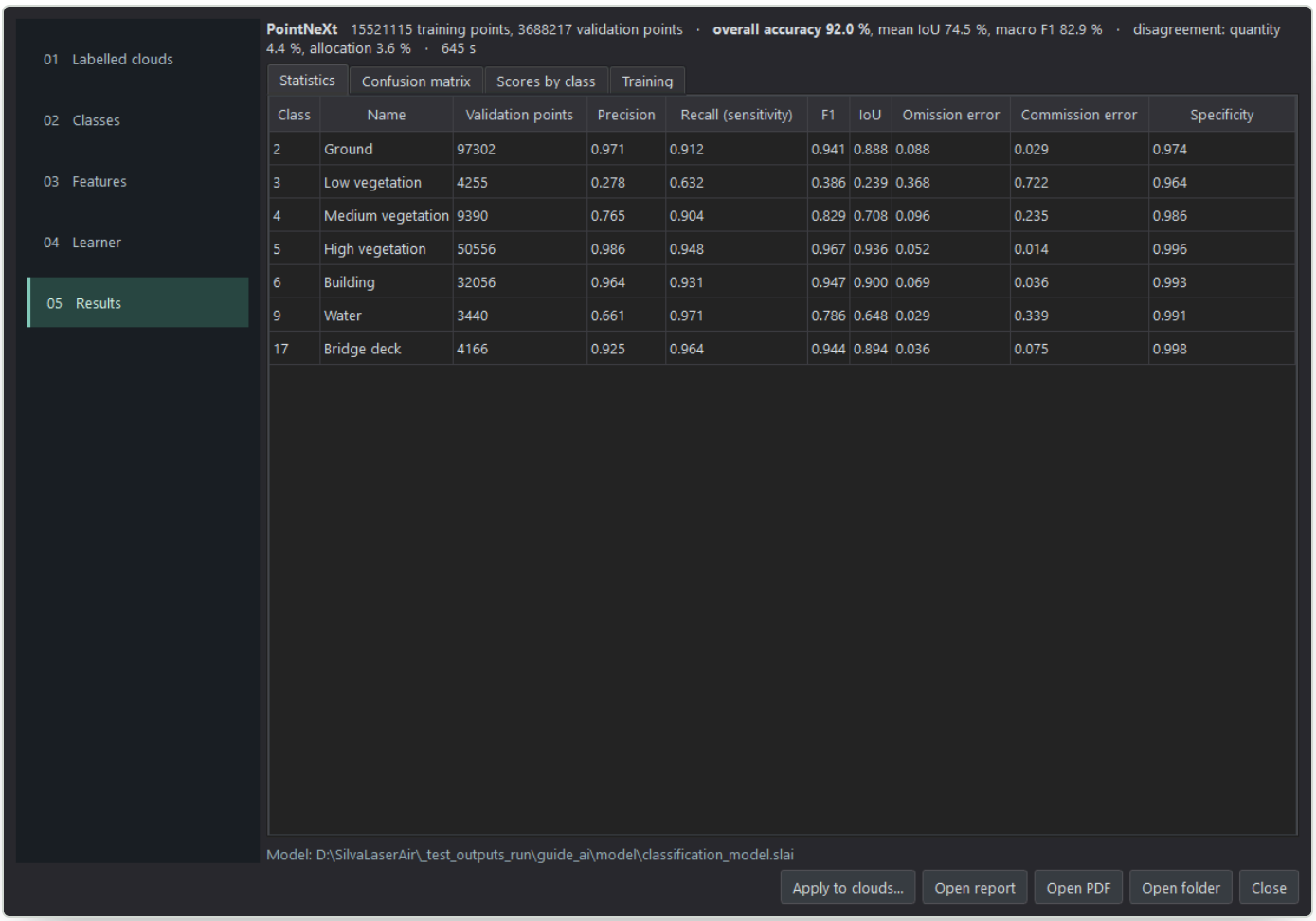


Figure C.10 The accuracy on the held-out blocks.

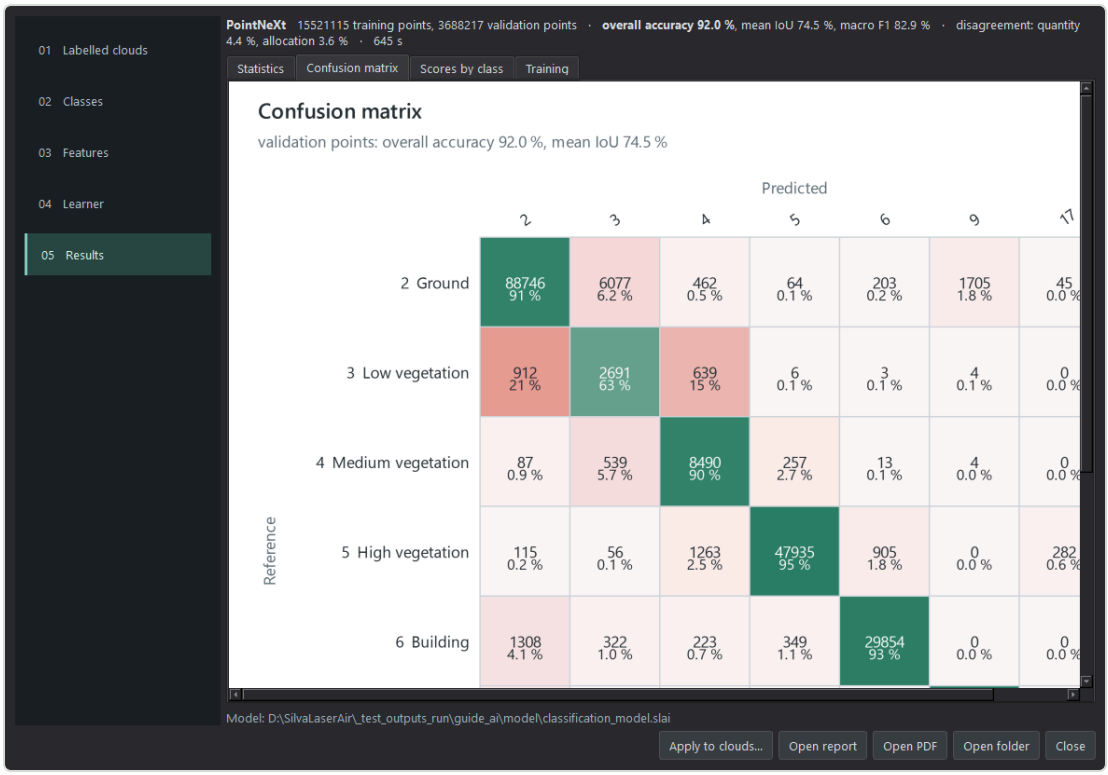


Figure C.11 The confusion matrix.

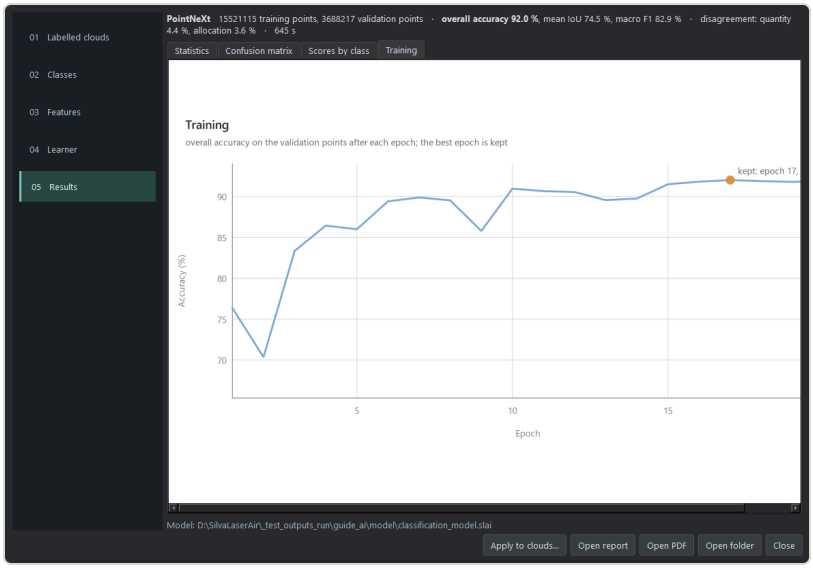


Figure C.12 The training curve: the accuracy on the held-out blocks after each epoch.

Part 5: Classify another cloud

1. *Click* **Apply to clouds…** (or *choose* **Apply a trained AI model** in the Classification panel), *choose* the clouds to classify, here central Paris.
2. **Keep the points of these classes as they are** keeps, for example, the ground of Ground Filtering. **Below this probability** gives class 1 to the points the model is unsure of.
3. *Click* **Classify**. Each cloud is written again with the new classes and every other attribute, and opens coloured by class.

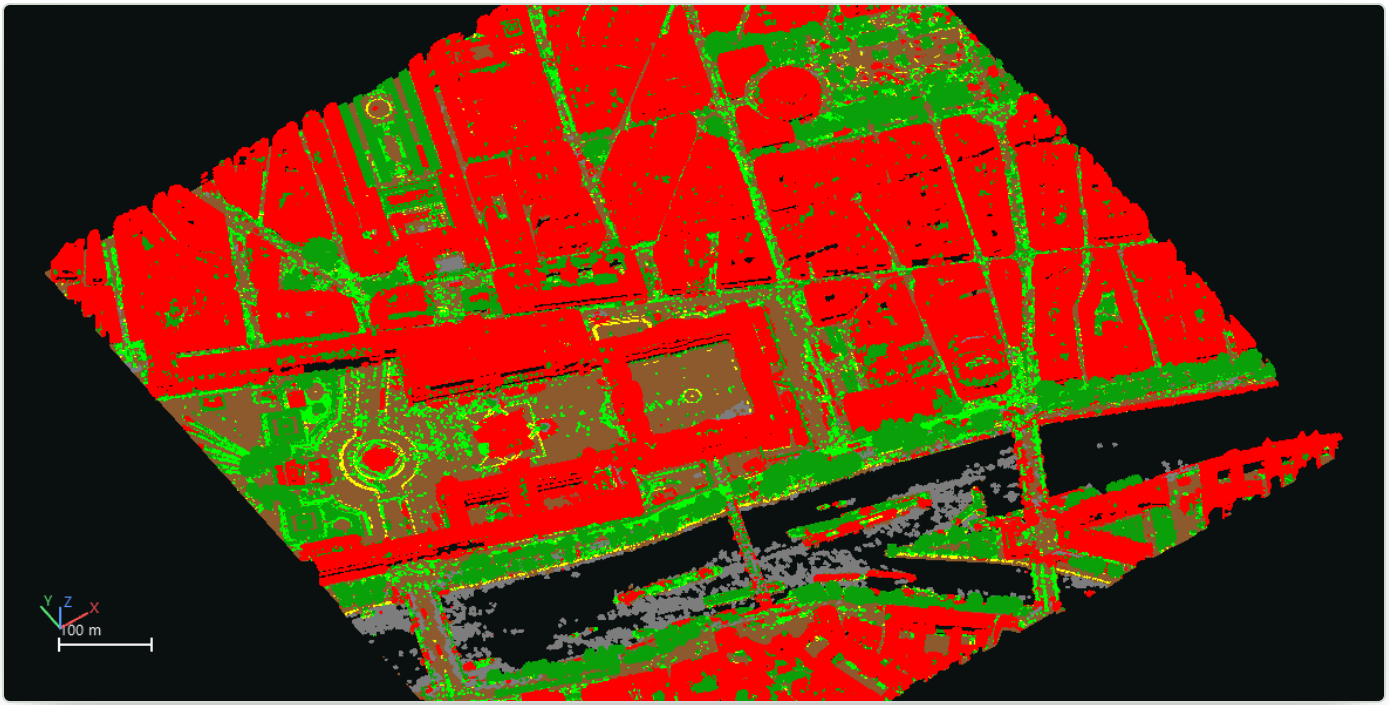


Figure C.13 Central Paris classified by the PointNeXt model learned in the Bois de Boulogne: buildings red, high vegetation dark green, ground brown.

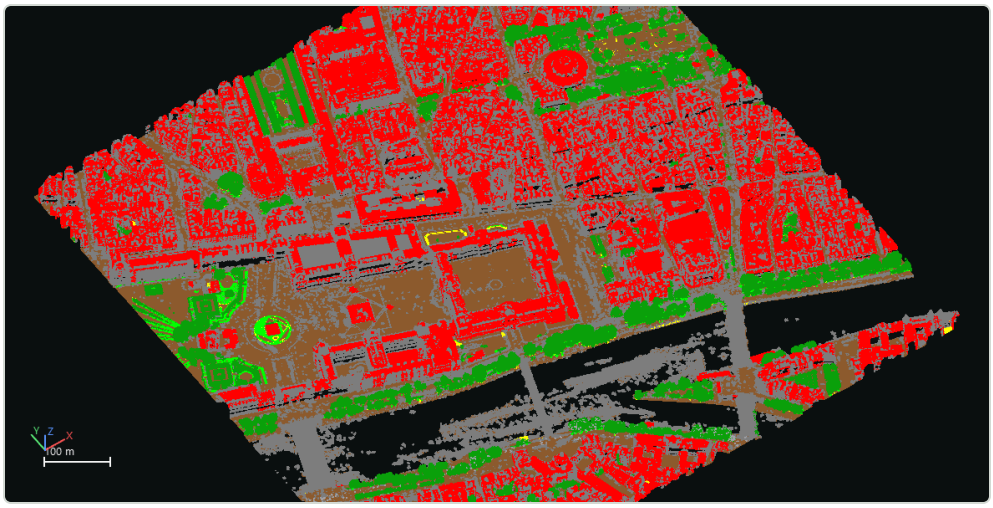


Figure C.14 The same view with IGN's own classes. IGN leaves many roof and street points unclassified (grey, class 1); the model was not asked to learn that class, so it gives those points one of the classes it learned.

Part 6: Continue training a model (fine-tuning)

1. To adapt a network to a new site, *open* **Train a Model…** with a few labelled clouds of that site, *tick* **Continue training a saved model** and *choose* the earlier model.
2. The network starts from what it learned and learns the new samples at a lower learning rate: far fewer labels are needed than from scratch. When the classes differ, a new last layer is made for them.
3. A Random Forest cannot continue: train it again with the earlier and the new samples together.

Note A model works best on data like the data it learned from: the same sensor, point density, season and kind of landscape. Check it on a few labelled places of new data before you trust it there.

Result You can label points, train your own classification models, judge them with sound accuracy measures, classify new clouds with them and adapt them to new sites.

Did you know? On central Paris, a PointNeXt model trained only on the Bois de Boulogne park classified 91 % of 14.5 million points like IGN did, with buildings at an F1 of 0.95.

Check your understanding

1. Why are the validation points held out in whole blocks?
2. Why can overall accuracy look good while a rare class is badly classified?
3. When would you fine-tune a model instead of training a new one?

Data credit

The example point cloud, `CapitolForest.laz` (Capitol State Forest, Washington, USA), is the sample dataset distributed with **FUSION / LDV** by the USDA Forest Service, Pacific Northwest Research Station. FUSION and its sample data: https://forsys.sefs.uw.edu/fusion/fusionlatest.html.

The 60 circular plots (`plots_poly.shp`, ID field `Id`) were placed at random by the author of this guide to illustrate the plot tools. They are not field plots and are not part of the FUSION sample data.

Demonstration A uses laser scans of a plot in the Austin Cary Forest, University of Florida: the mobile (MLS) and terrestrial (TLS) scans were collected by SilvaLab, and the drone (UAV) LiDAR was provided by Prof. Eben Broadbent, SPEC Lab (GatorEye), University of Florida. They are not distributed with this guide. Demonstration B and Exercise 9 use airborne LiDAR and forest inventory data of Fazenda Cauaxi, Pará, Brazil, acquired with support from USAID and the US Department of State with the technical assistance of the Brazilian Corporation for Agricultural Research (EMBRAPA) and the US Forest Service Office of International Programs via the Sustainable Landscapes Brazil Project; please cite Silva, C.A.; Hudak, A.T.; Vierling, L.A.; Klauberg, C.; Garcia, M.; Ferraz, A.; Keller, M.; Eitel, J.; Saatchi, S. Impacts of Airborne Lidar Pulse Density on Estimating Biomass Stocks and Changes in a Selectively Logged Tropical Forest. *Remote Sens.* 2017, 9, 1068, doi.org/10.3390/rs9101068.

Demonstration C uses two tiles of the French national LiDAR, IGN LiDAR HD (Bois de Boulogne LHD_FXX_0645_6862 and central Paris LHD_FXX_0651_6863, flown in March 2023): © IGN – LiDAR HD, Etalab Open Licence 2.0, geoservices.ign.fr/lidarhd.