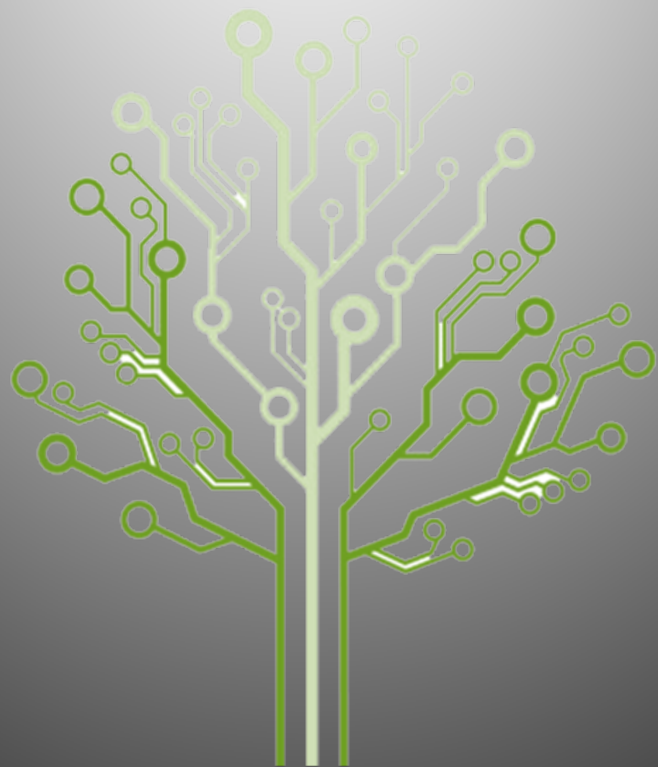
3D TECHNOLOGIES IN MONITORING FOREST STRUCTURES



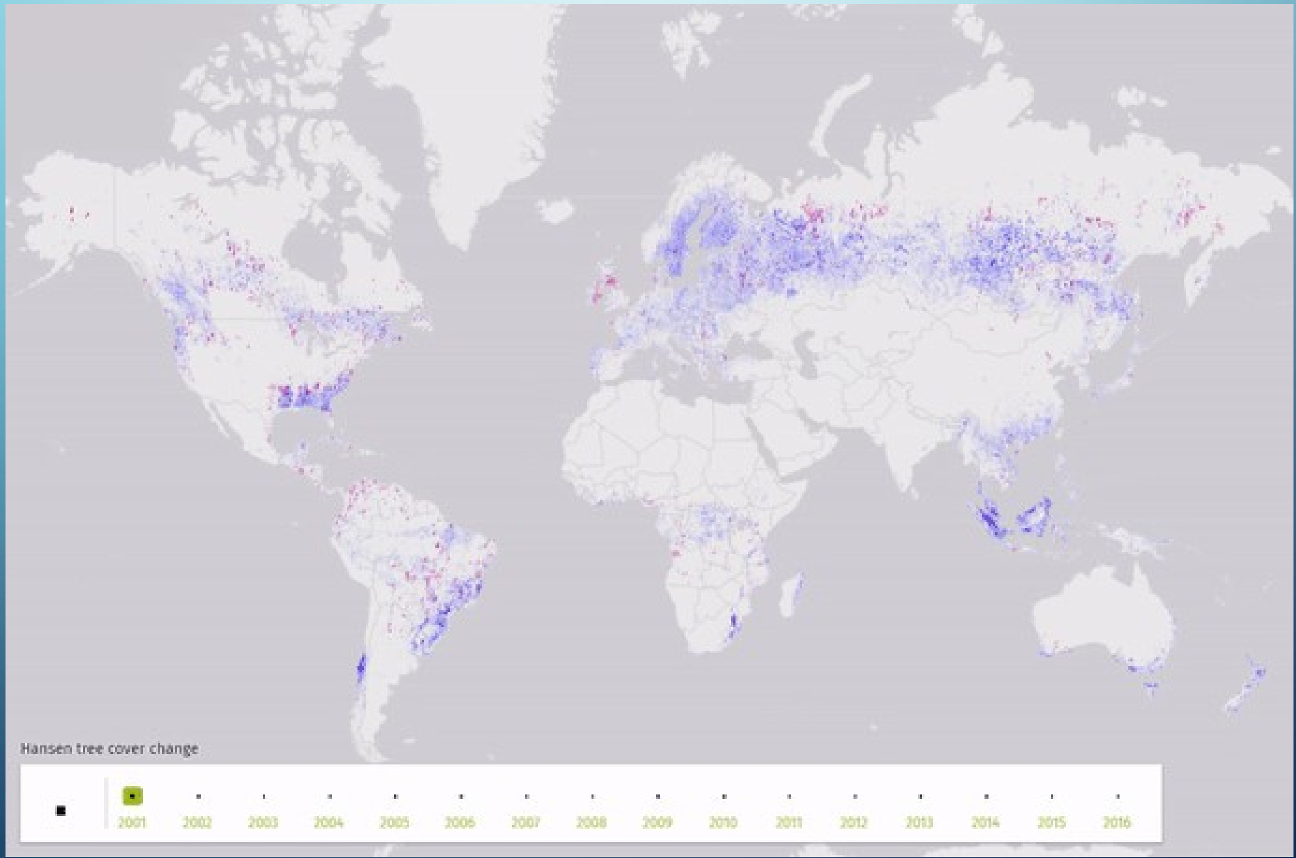
MIHAI-DANIEL NIȚĂ

Transilvania University of Brasov

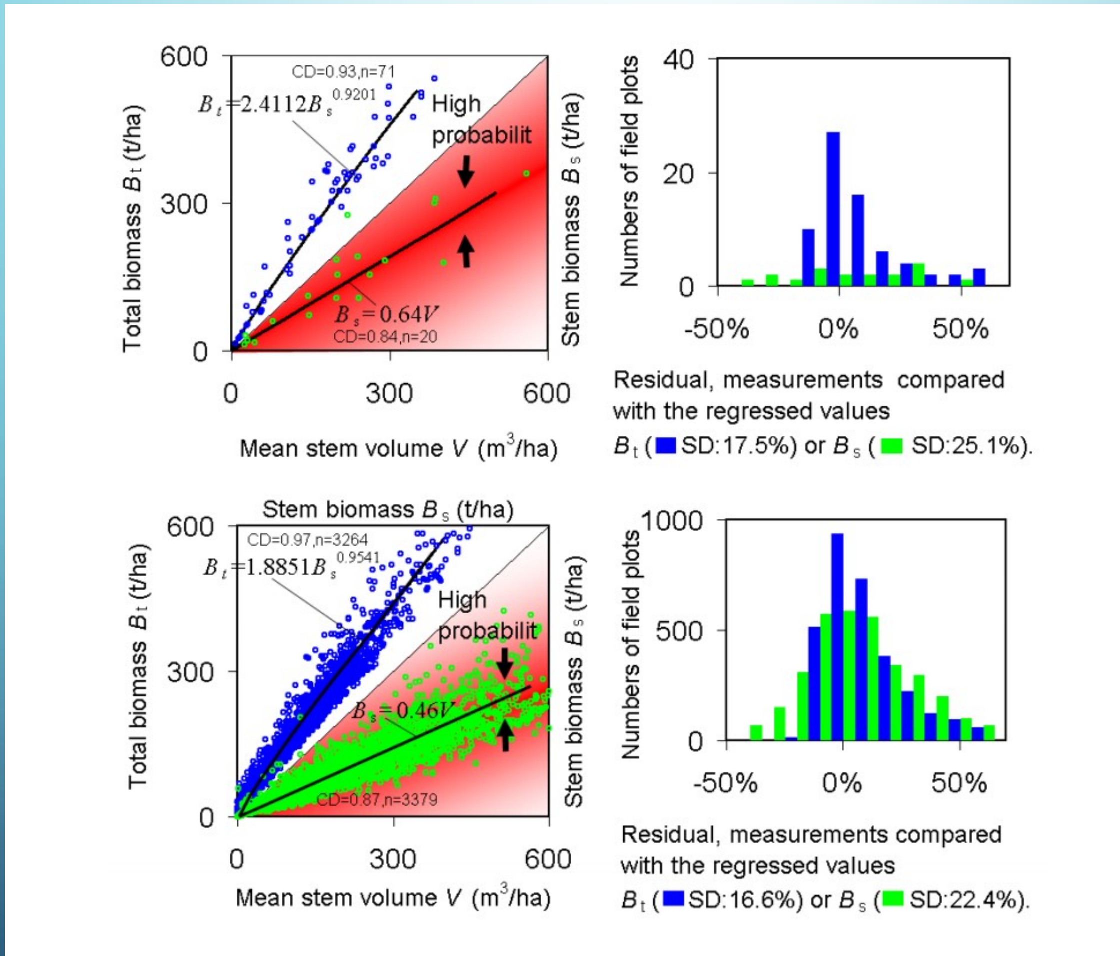
Forest design®
the nature in digital format

TIMBER WORLDWIDE

- **Total worldwide processed wood is 3.5 Billions cubic meters annually (FAO).**
- **Total certified volume of FSC (Forest Stewardship Council) wood produced annual is 300 MM of total world wood production**
- **Approx.. 10% of the timber has certified origin**



THE FACT is that we don't have a real estimation of the standing volume in the forests worldwide

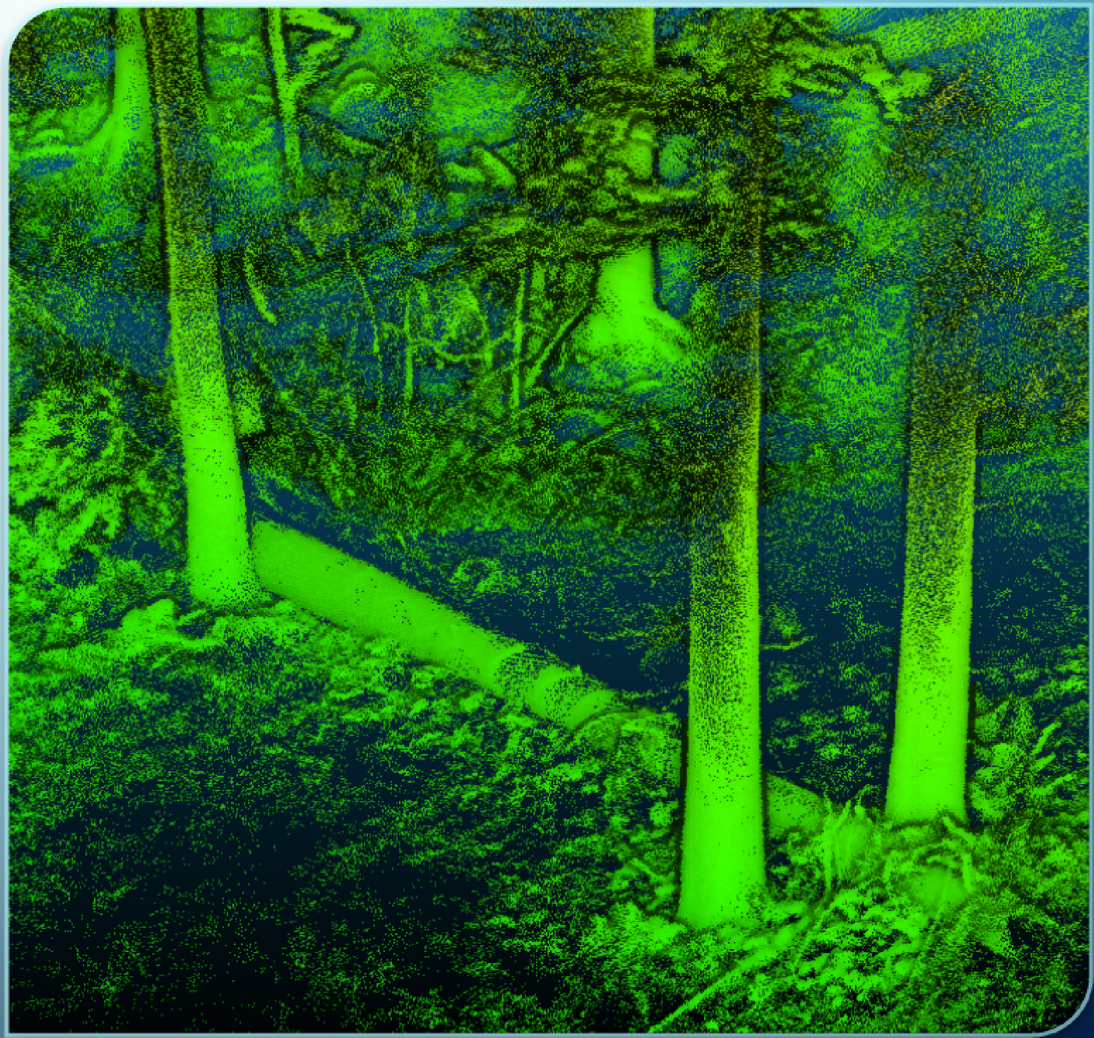


WHY?

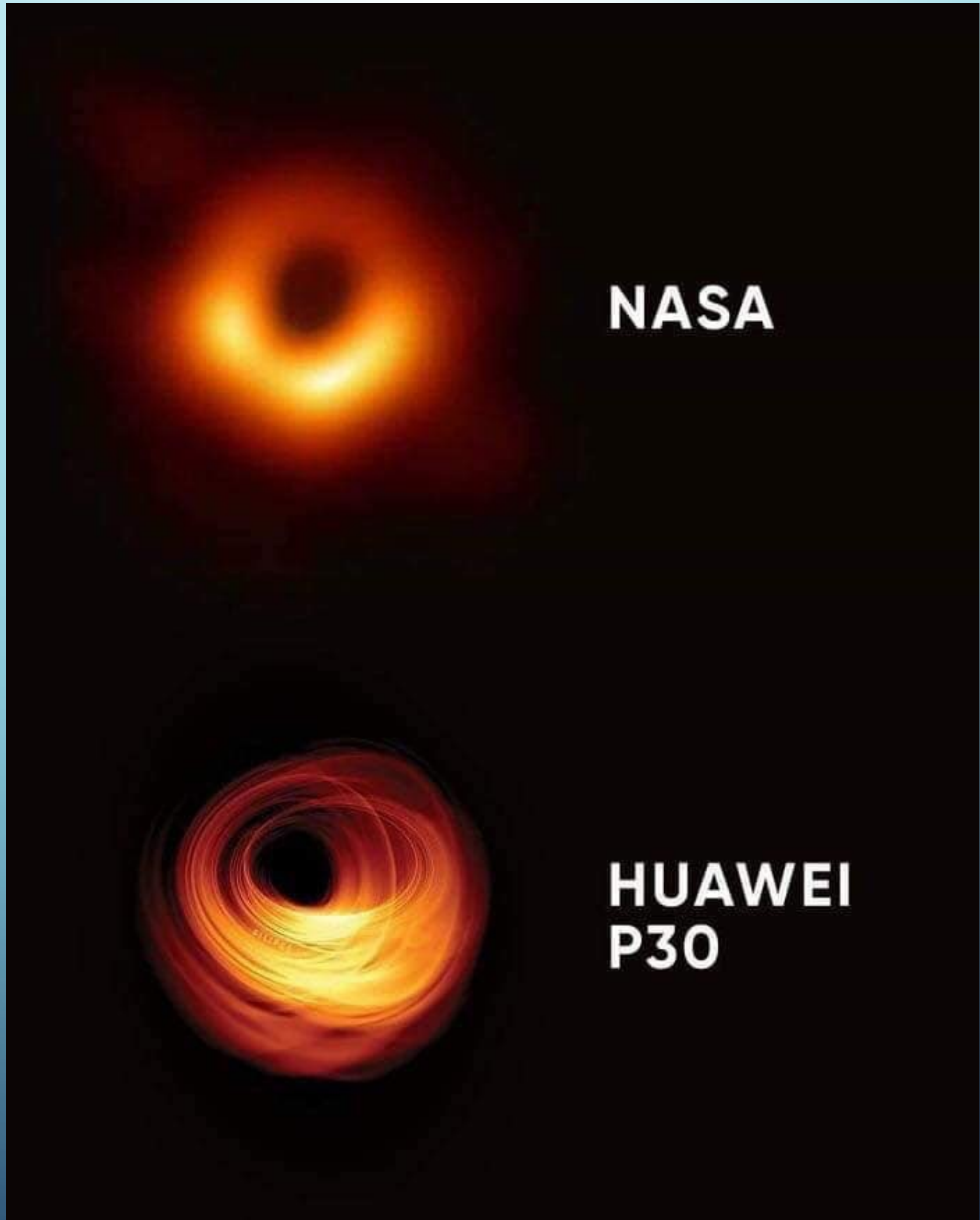
Liu et al.,2017

WHY?

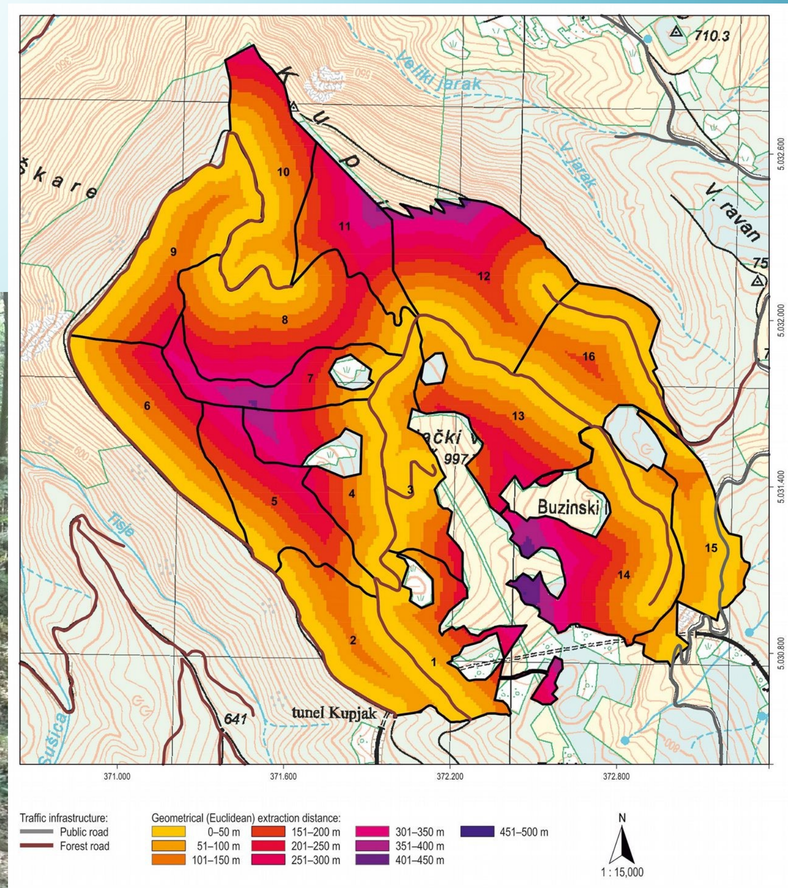
- *Many* ***forest spaces are complex and difficult to access.***
- *Precise mapping that take readings from forests are often made with* ***huge time allocation*** *and considerable costs,*
- *Forestry professionals want to access* ***user-friendly technology***



PEOPLE ARE LOOKING FOR SIMPLE INFORMATION TO INGEST



THE MANAGERS AND PEOPLE IN THE FIELD ARE CONNECTED WITH GROUND TRUTH



SO, FOREST MANAGERS (AND MANGERS IN GENERAL) ARE INTERESTED MORE IN **SIMPLE DATA**, EASY TO READ, FASCINATINGLY BEAUTIFUL…

…ON A MAP

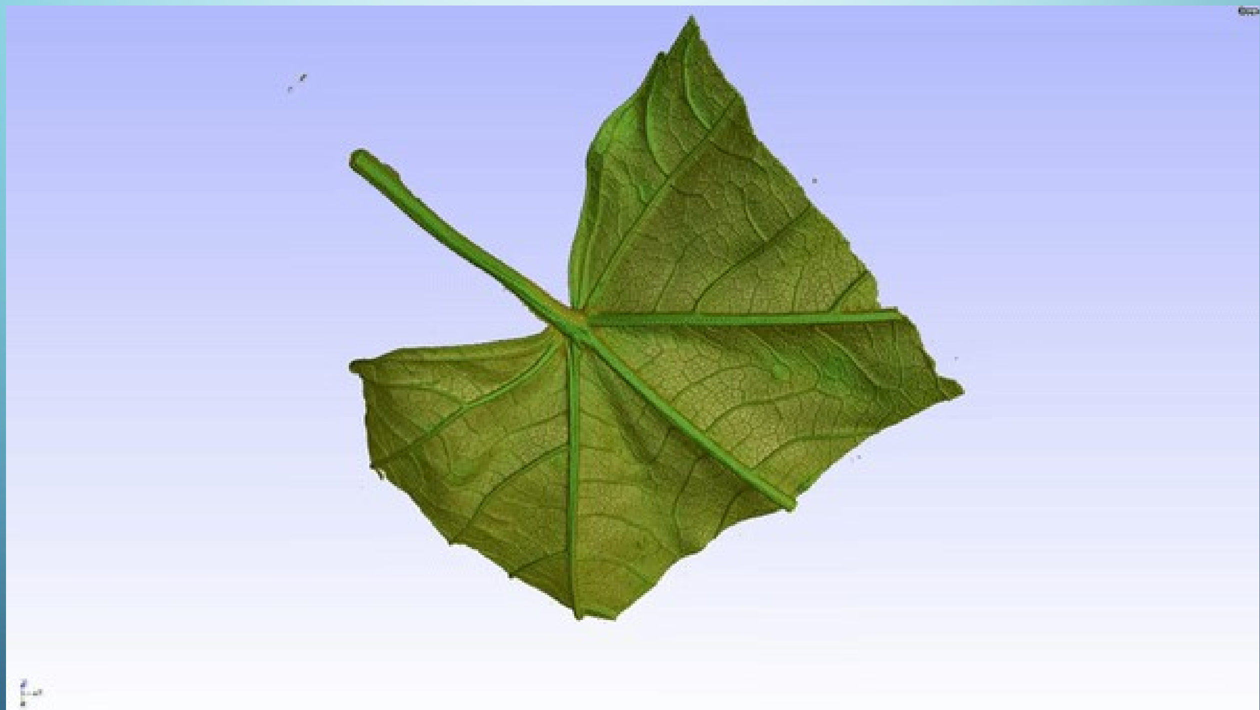
…ON THEIR PHONE

IN THE MODERN ERA WE CAME OUT WITH **PIXELS**

- In digital imaging, a pixel is a physical point in a raster image, or the smallest addressable element in an all points addressable display device

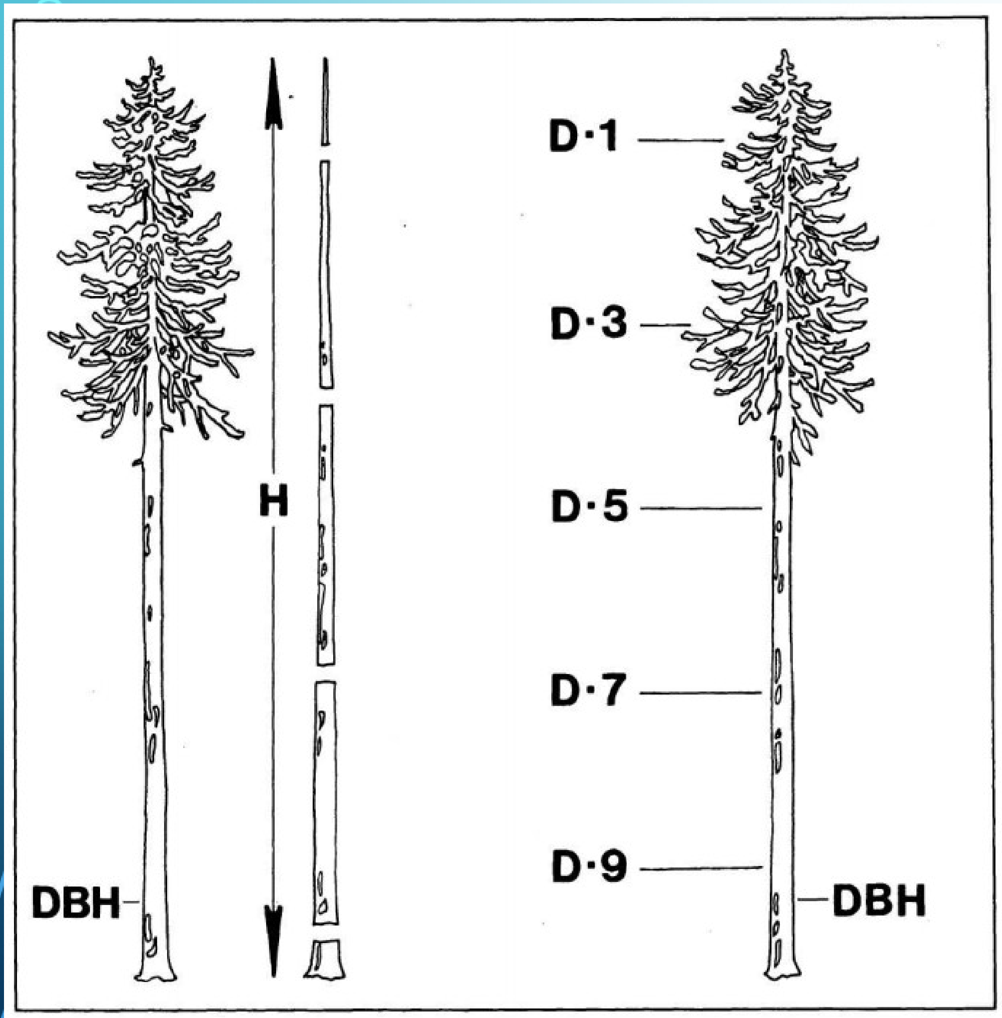
BUT WE ARE LIVING IN A 3D WORLD… NOWADAYS WE CAME OUT WITH **VOXELS**

- A voxel represents a value on a regular grid in three-dimensional space.
- The word *voxel* originated by analogy with the word "pixel", with *vo* representing "volume" and *el* representing "element"



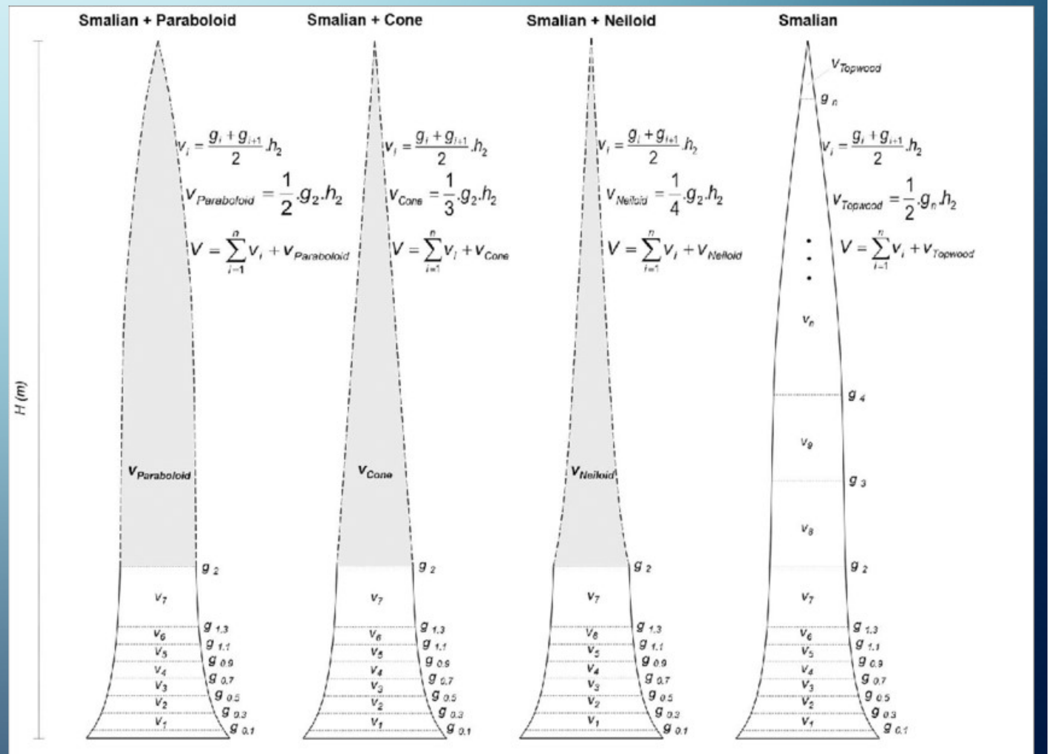
3D rendering of a μCT scan of a leaf piece, resolution circa 40 μm/voxel when viewed at the full size

WHAT ABOUT FORESTS?

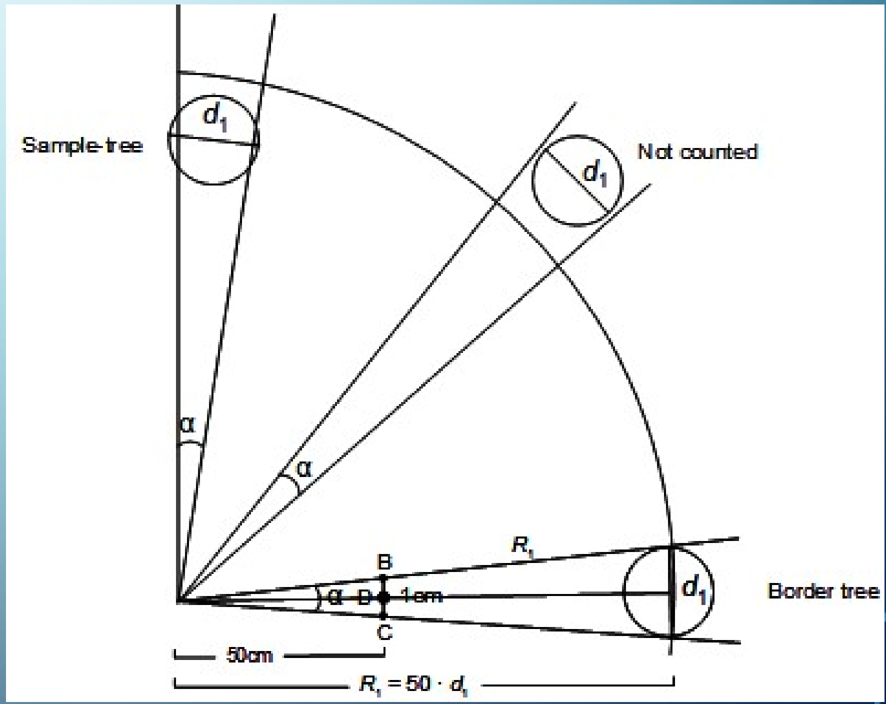


We are fitting complex tree shapes using a diameter and a height – both affected by errors

Leading to errors up to more or less 50%

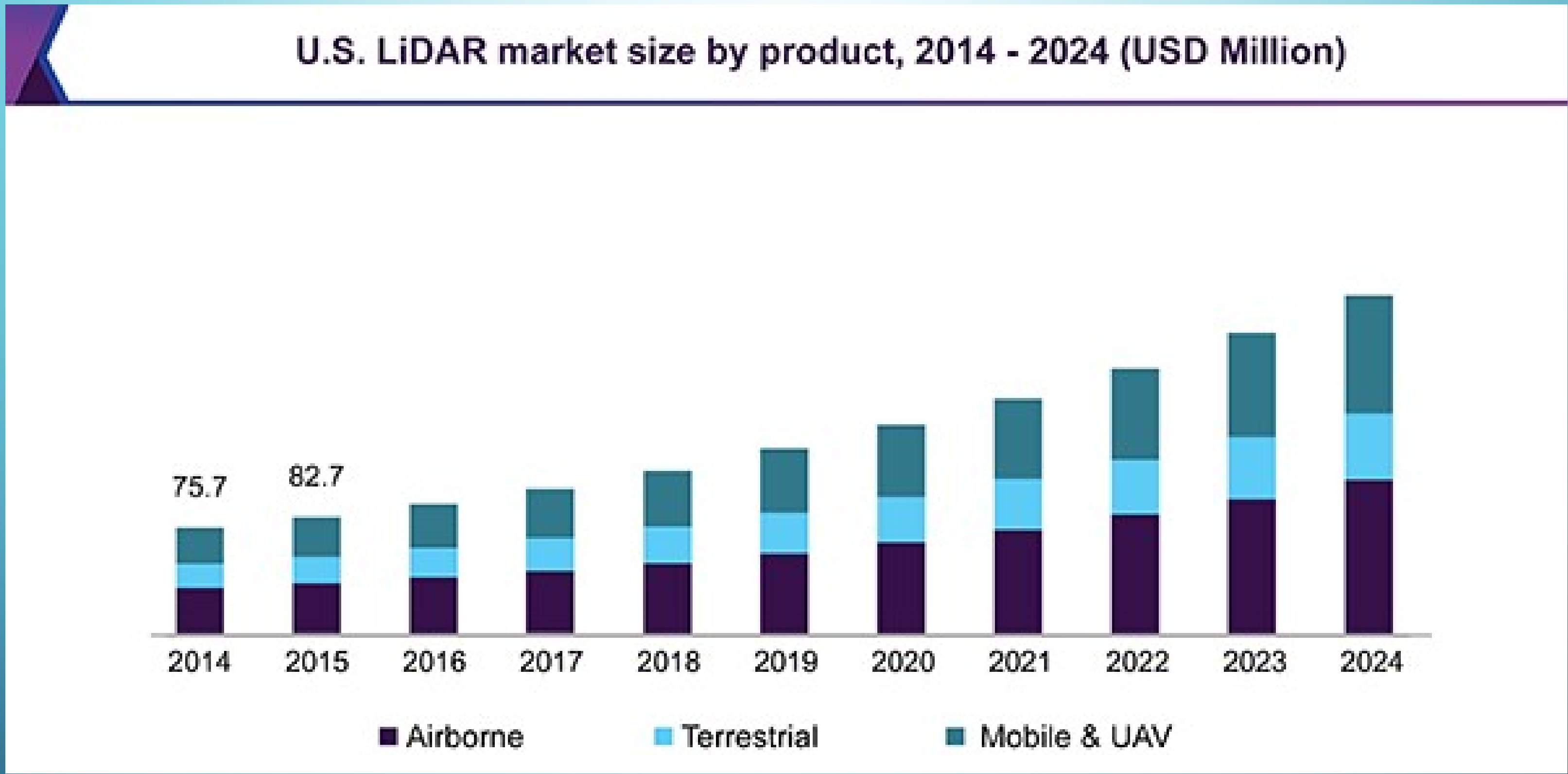


FORESTERS: WHY TO USE 3D DATA?
WE'VE GOT BITTERLICH!!! IS ACCURATE ENOUGH...



Based on Kramer H. and A. Akca. 1995. Leitfaden zur Waldmesslehre. 3rd edition. J.D. Sauerländers Verlag, Frankfurt. 266p.

3D SCANNERS – CHANGE IN PARADIGM



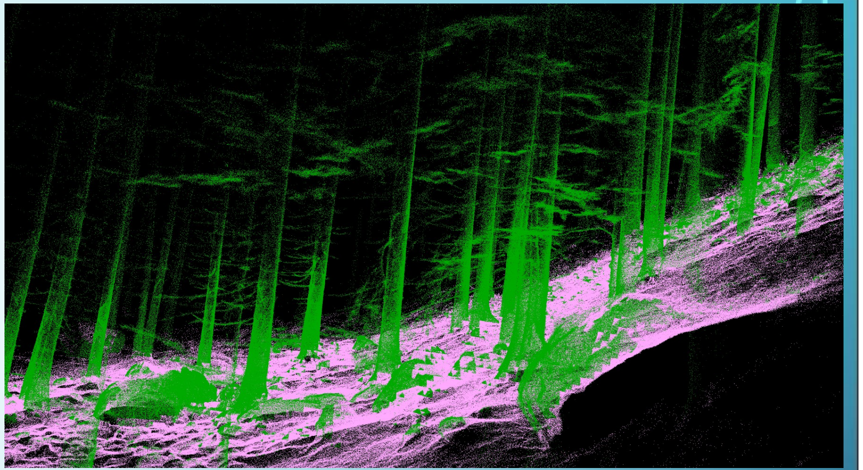
North America 3D scanning market size, by application, 2012-2024 (USD Million)

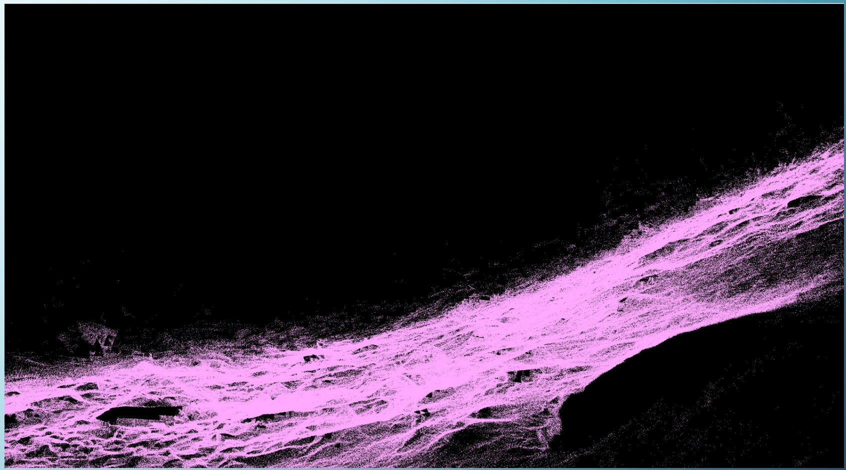
MOBILE SOLUTION

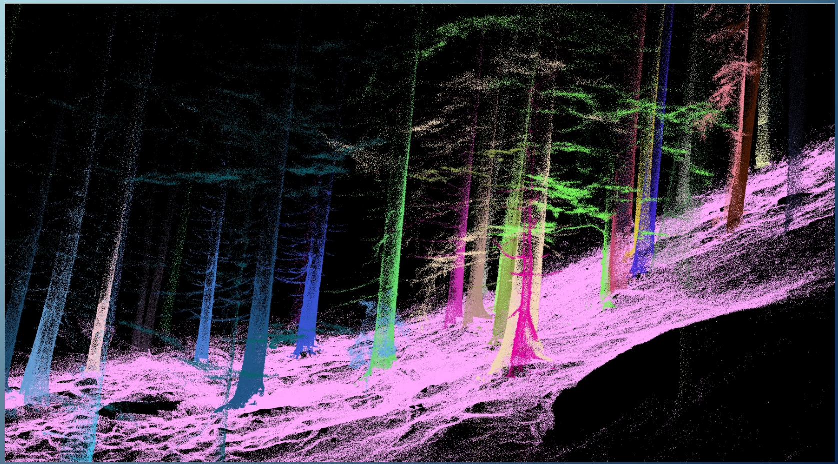
- **Lightweight, handheld** laser scanner which is highly mobile, simple to operate and can be used by anyone.
- Need a **versatile technology** which is adaptable to any environment, especially complex and enclosed spaces, without the need for GNSS.

SOLUTION

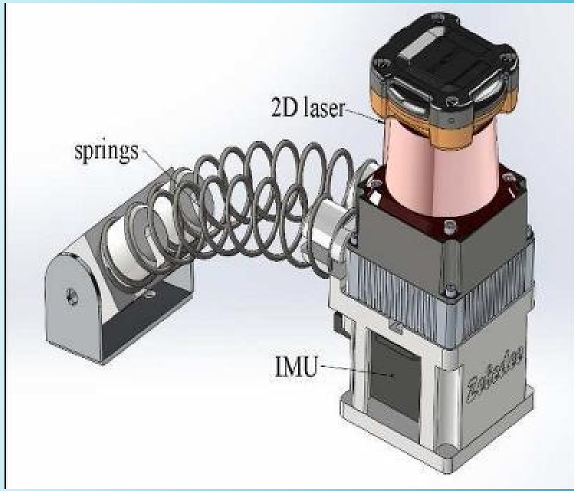
- We tested GEOSLAM HORIZON performance in the forest:
- produces **10 million points/ minute**
- laser range is **100 m**
- in 10 minnutes scans approximately **1 ha of forest**



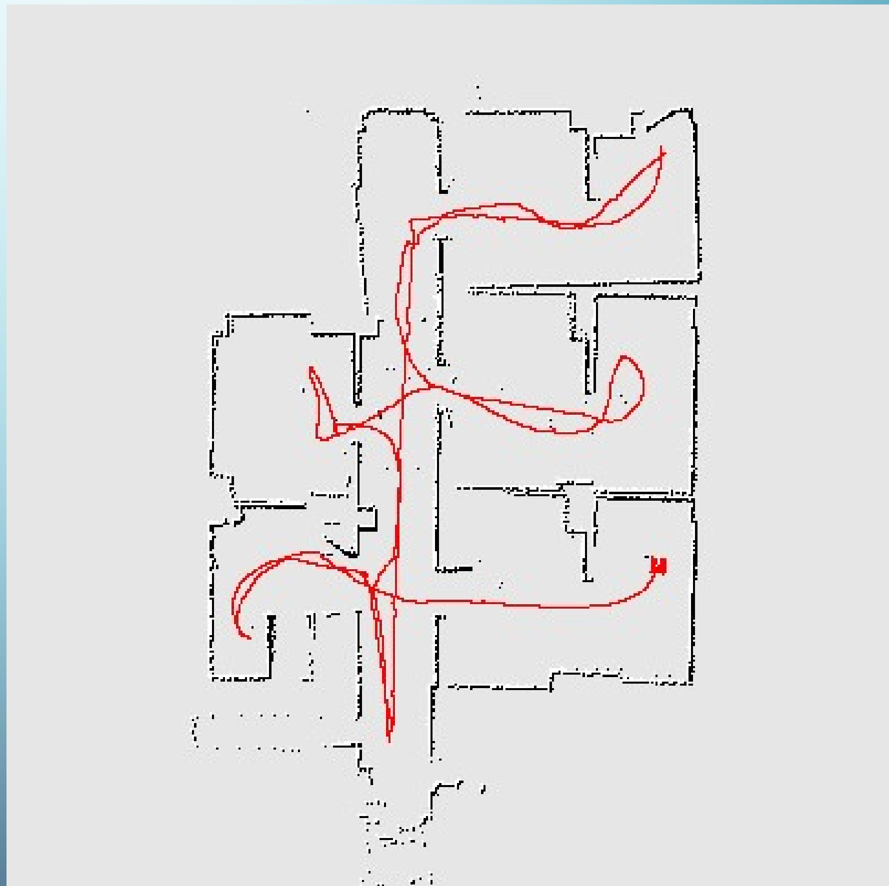




PRINCIPLES OF FUNCTIONING



- GeoSLAM's algorithm utilises **data from a Lidar sensor and inertial measurement unit (IMU).**
- The IMU is used to estimate an initial position and create a point cloud from which **surface elements are extracted to represent the unique shapes** within the point cloud.
- The **trajectory is then calculated** for the next sweep of data using the IMU and surface elements extracted again in the same way.

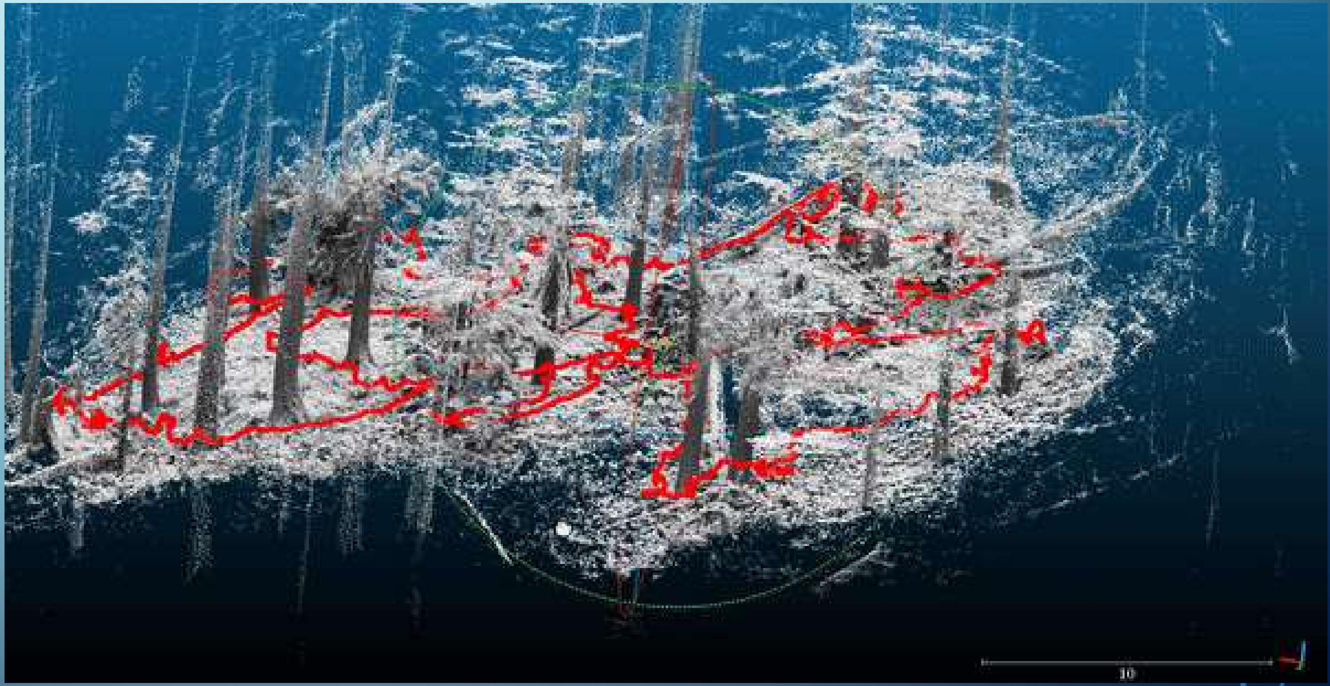


www.societyofrobots.com

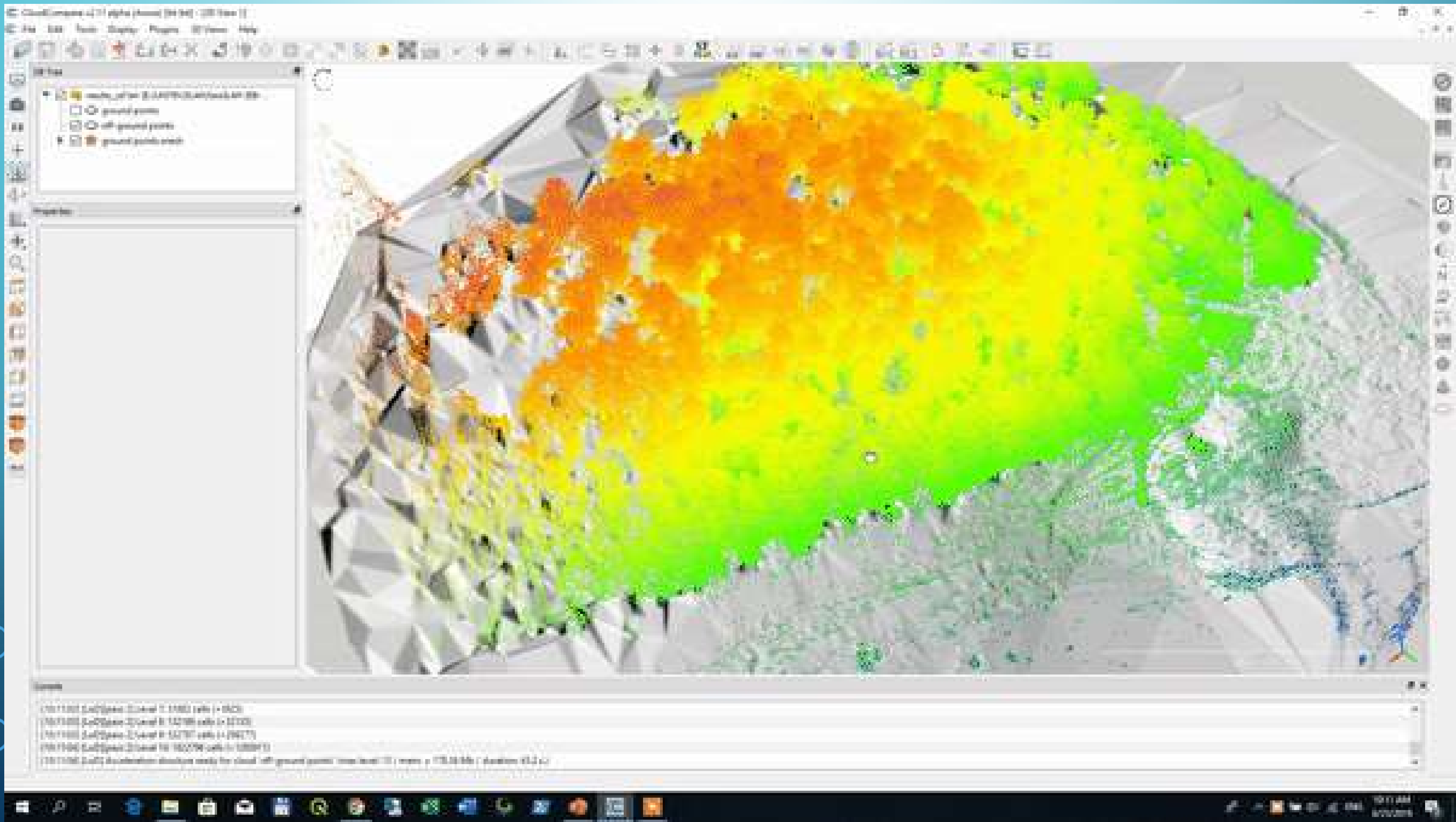
PRINCIPLES OF FUNCTIONING

- What is SLAM?
- In robotic mapping and navigation, **S**imultaneous **L**ocalization **A**nd **M**apping (**SLAM**)

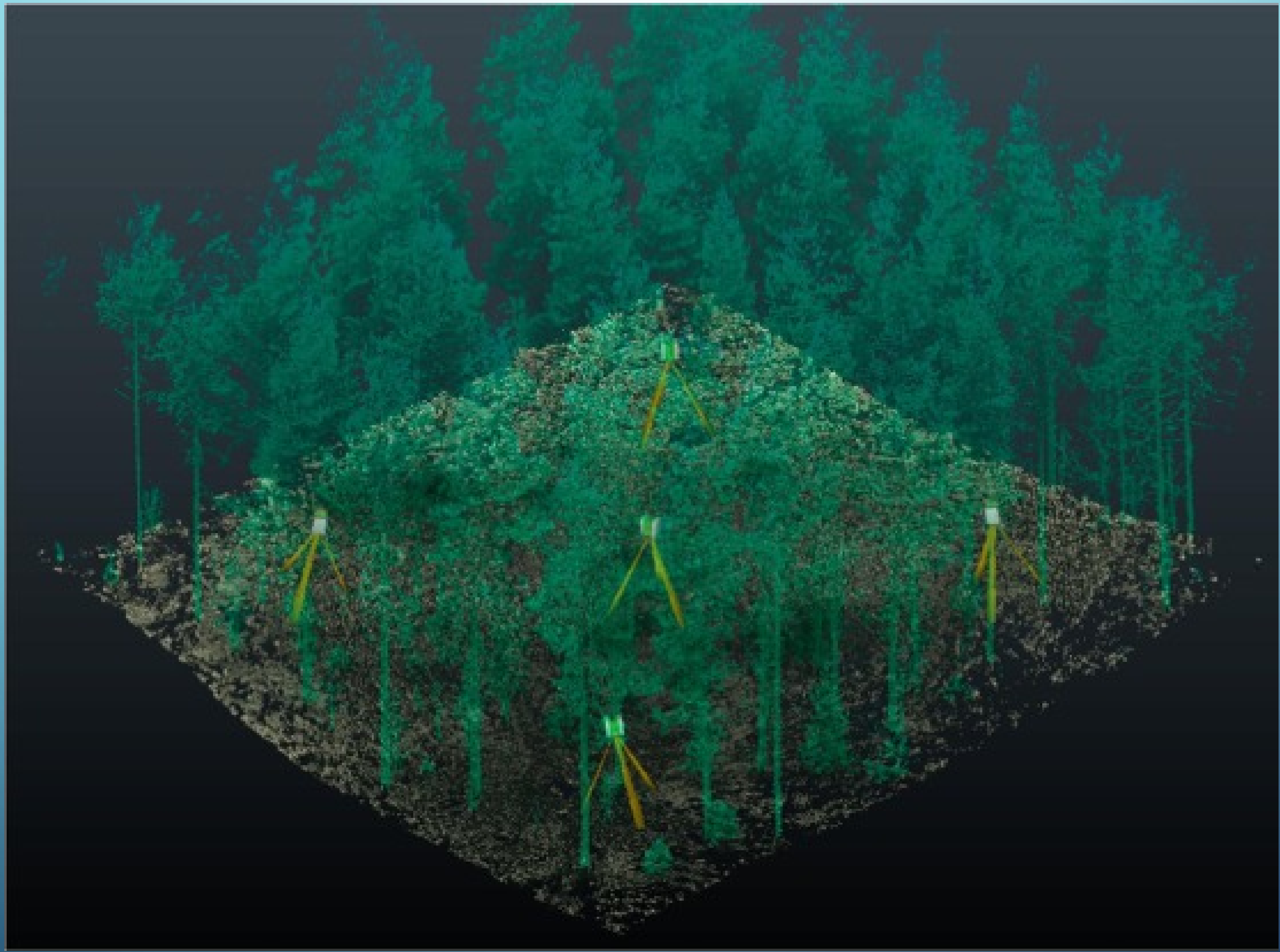
is the computational problem of constructing or updating a map of an unknown environment while simultaneously keeping track of an agent's location within it.



EXAMPLE GEOSLAM HORIZON 10 MINUTES = 1.5HA

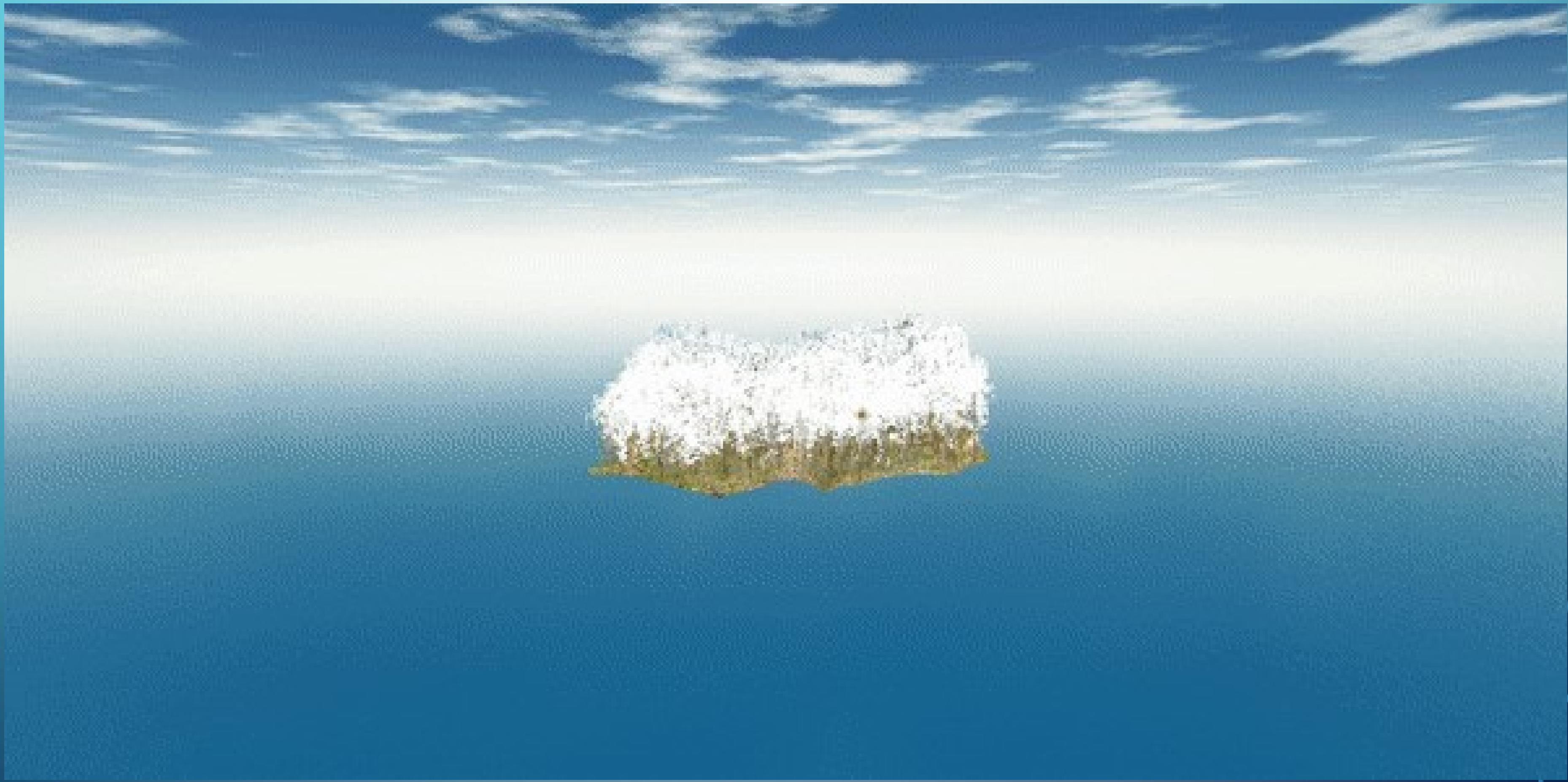


TRIPOD SOLUTION – FOR NOISE UNDER 1CM

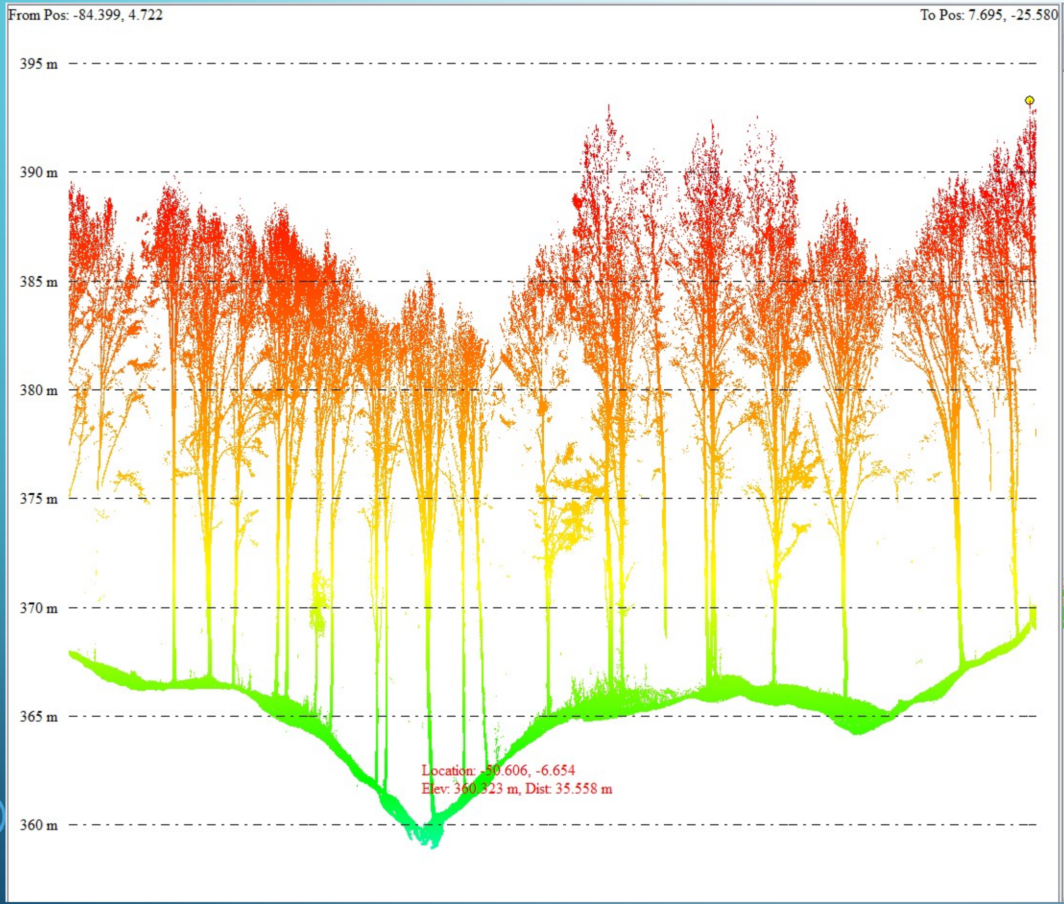


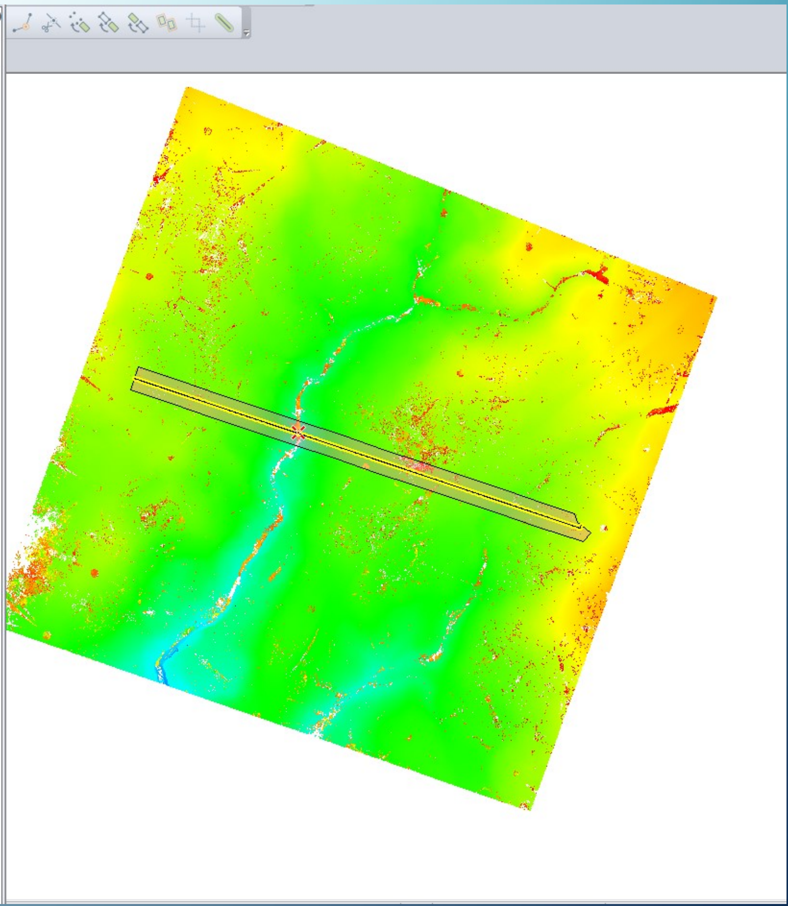
Liang et al 2018

EXAMPLE – FARO S70 – 5HOURS 1 HA



OK. SO WE HAVE A VERY NICE POINTCLOUD…





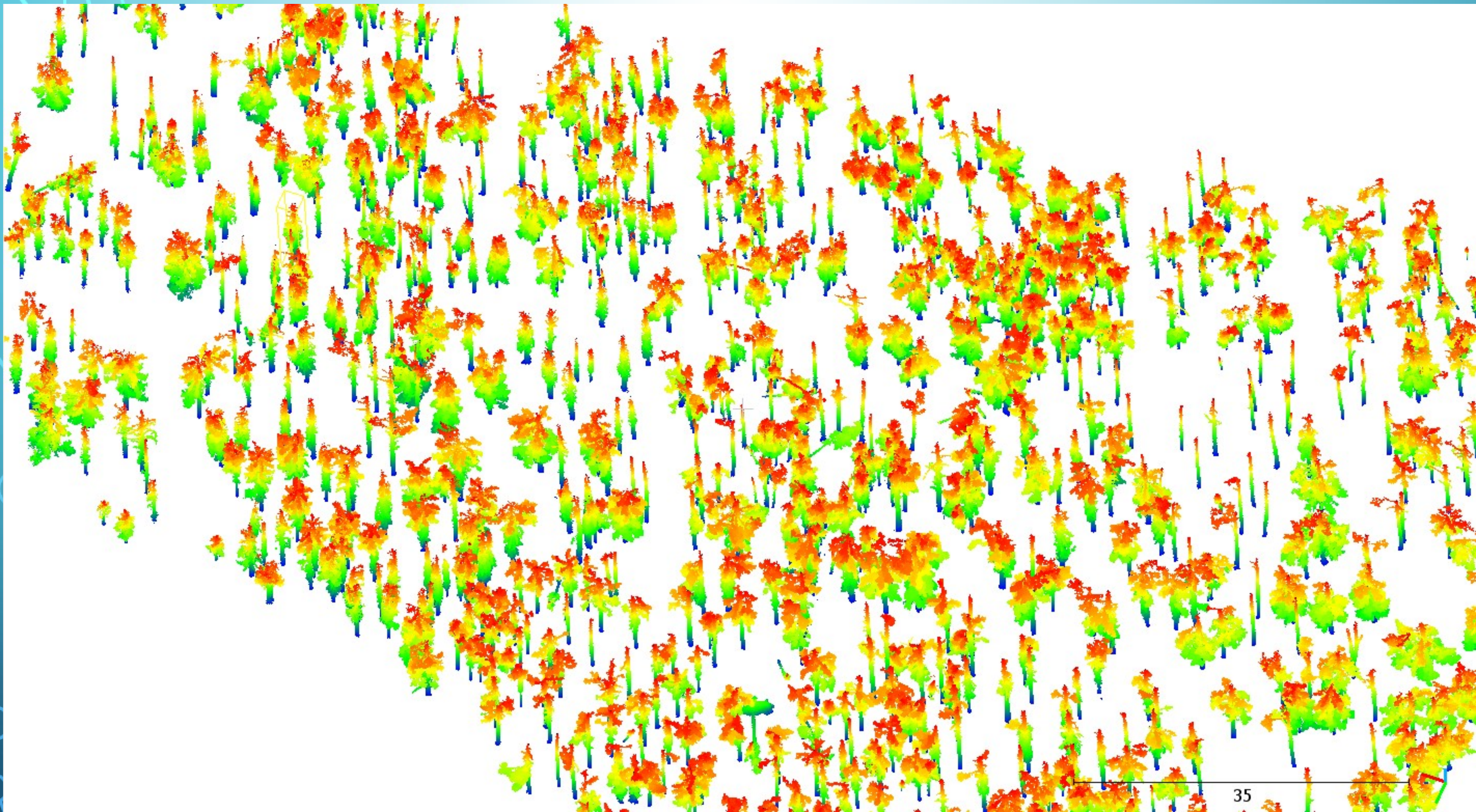
GOING BACK TO THE QUESTIONS OF FOREST MANAGERS:

- What is the standing volume?
- What is the harvesting possibility and technology
- Selective logging for maintaining diverse structure for biodiversity?
- Can I get it in real-time?

Etc.

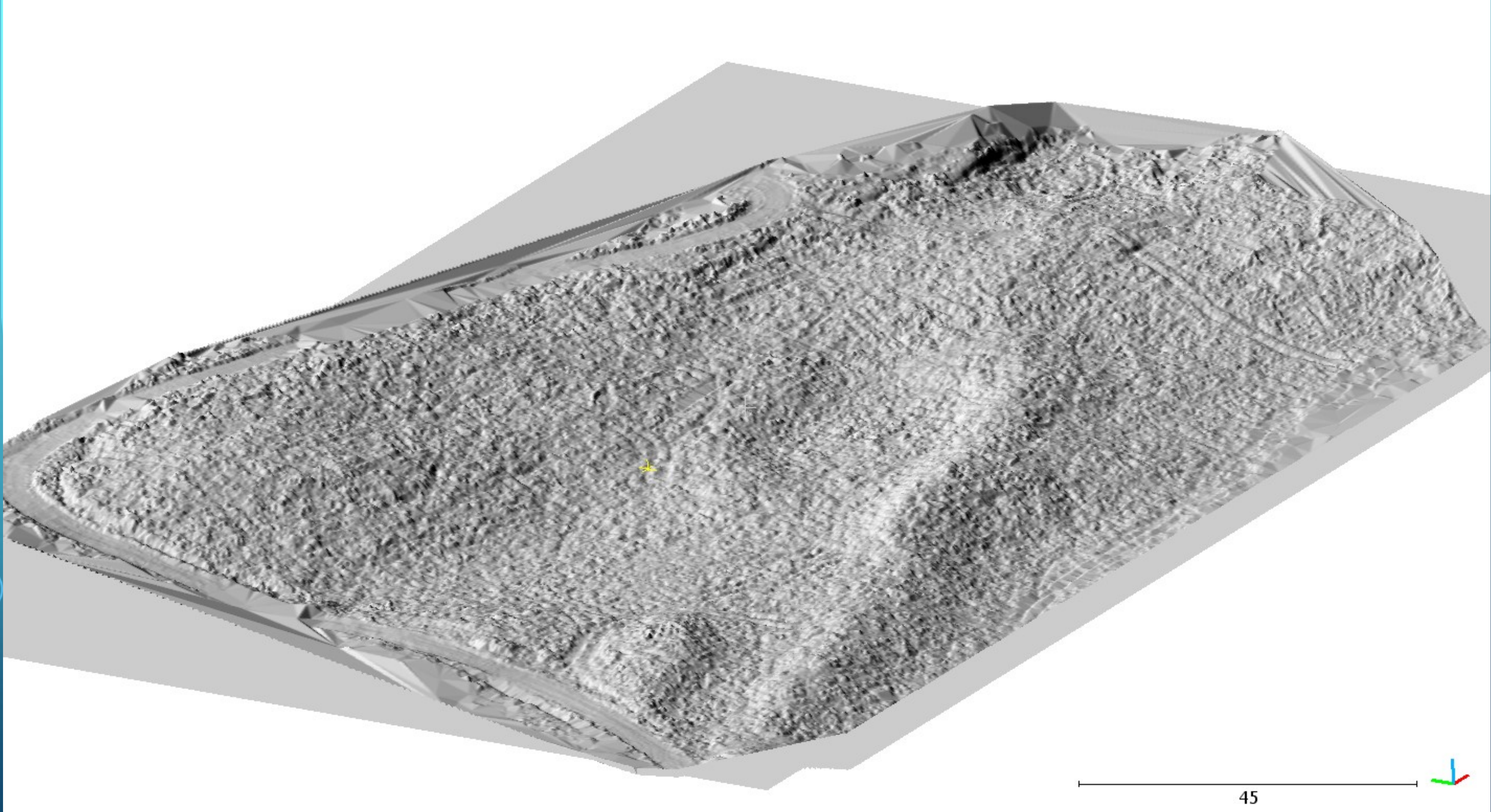
SEMI-AUTOMATIC (MANUAL) TREE EXTRACTION AND VIRTUAL MEASUREMENTS FROM LIDAR IMAGERY

Segmentation



Tree by tree segmentation and labeling – 1141 trees for Demo Site in Finland

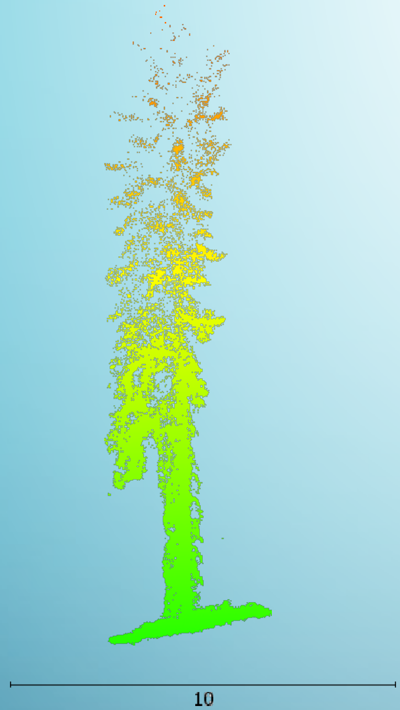
Digital Elevation Model



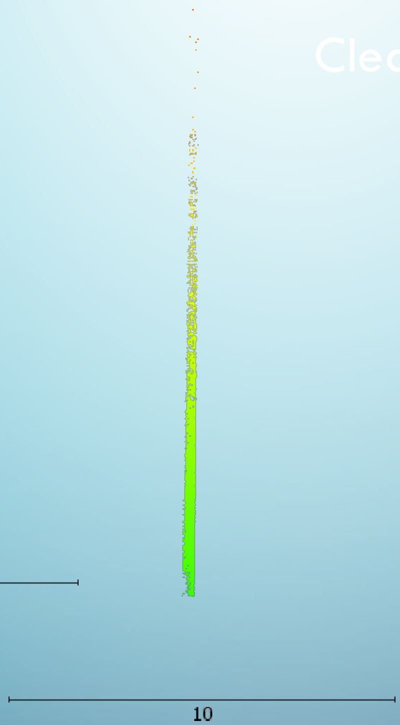
Digital elevation model for estimating the correct Breast Height at 1.3

Cleaning tree models - Manually

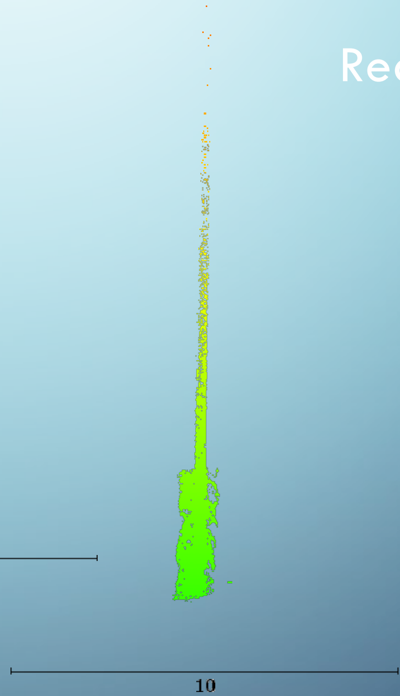
Initial cloud from scanner



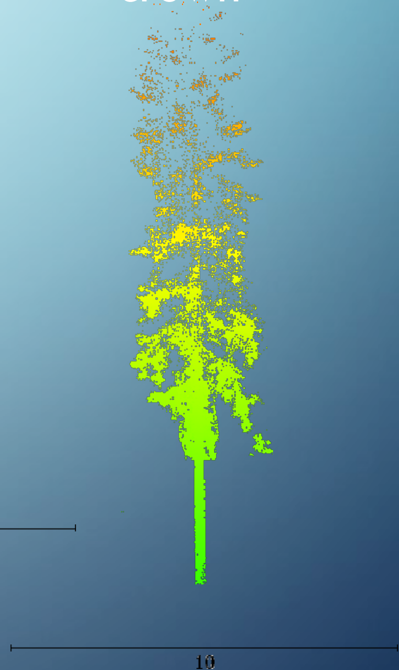
Debranching



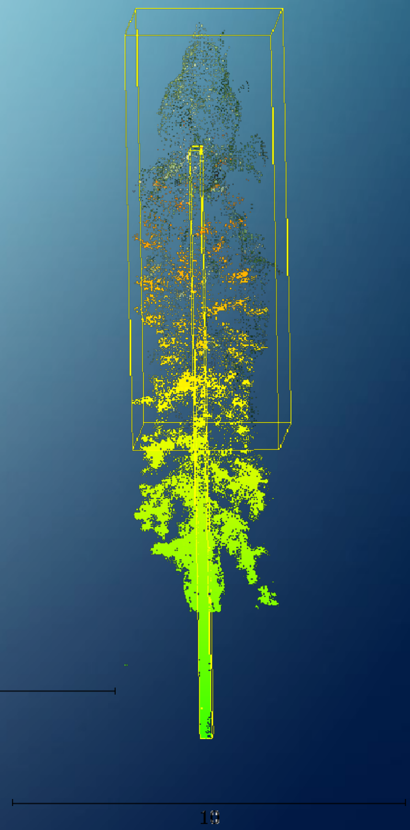
Clearing the DBH area



Reattaching the crown



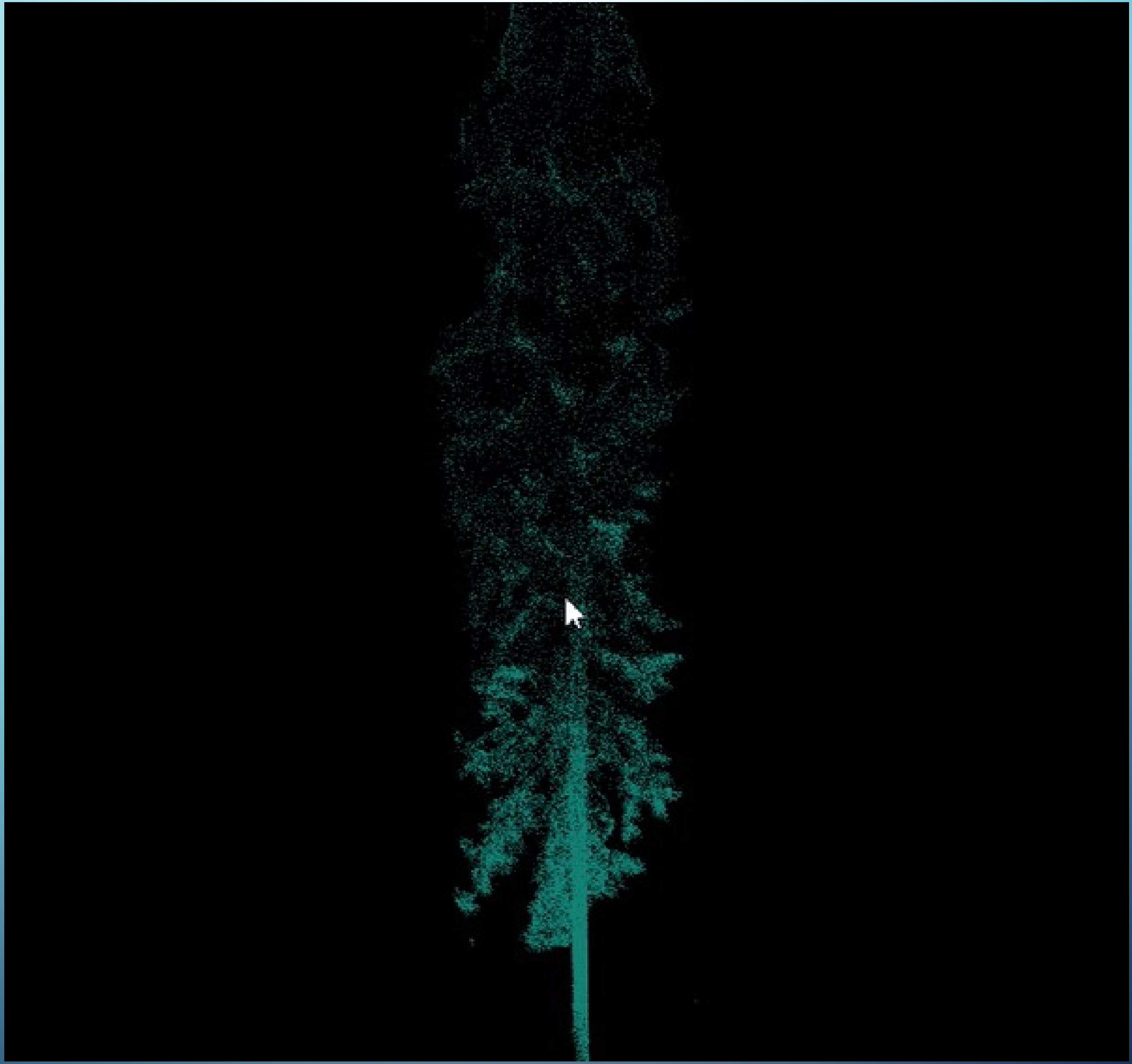
Point cloud fusion with drone – adding tip of the crown



We cleared the stem area from 0 to 2 m of branches and other neighboring trees which were not detected automatically.

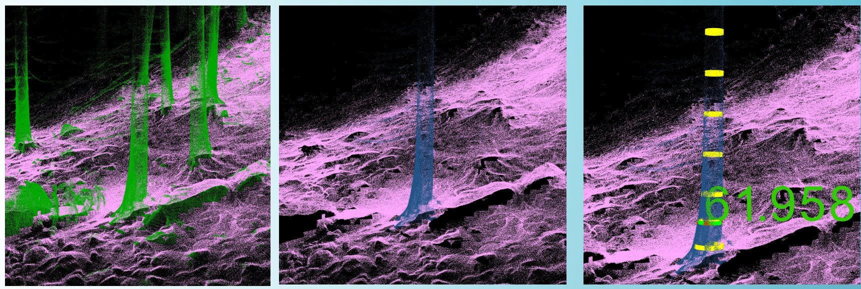
Time? Don't ask!

Extracting tree characteristics - automatically

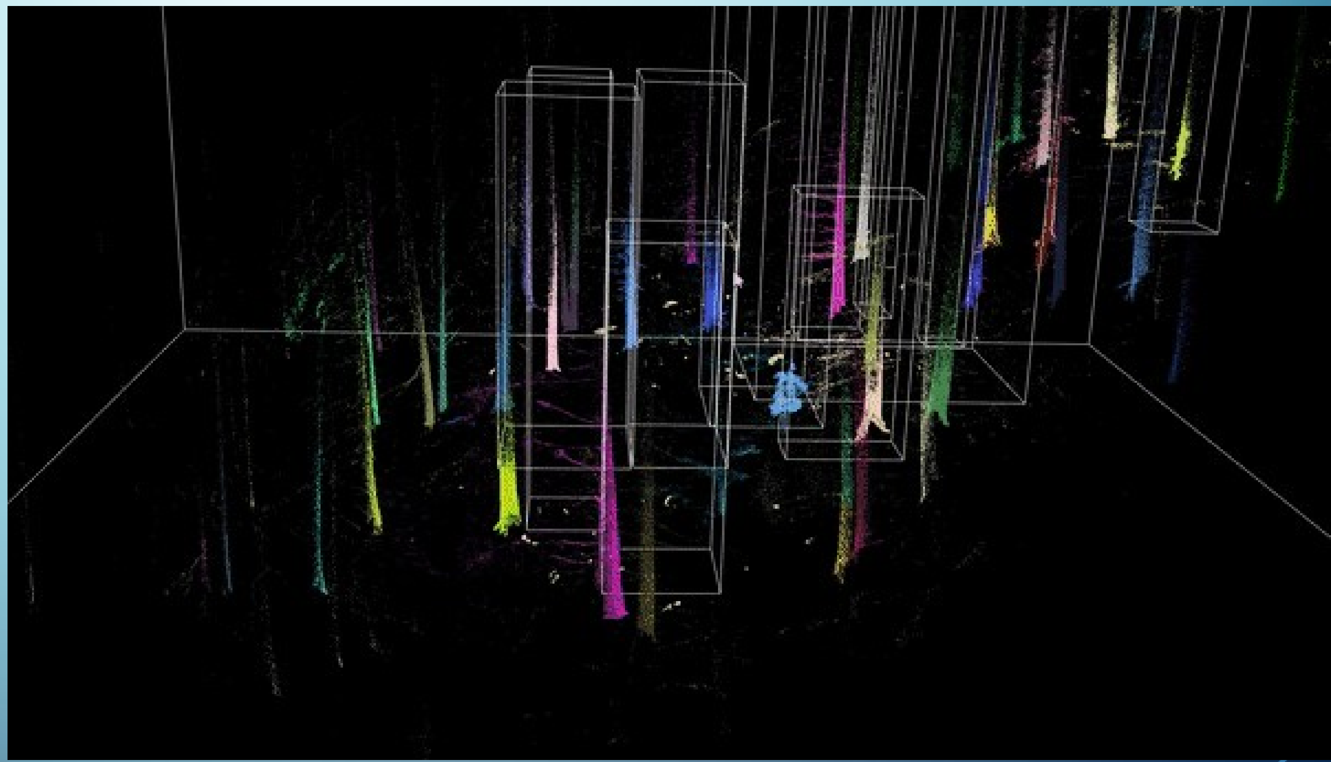


Extracting data for every tree: XYZ position, DBH, Height, Crown
3D Forest Open Source Software

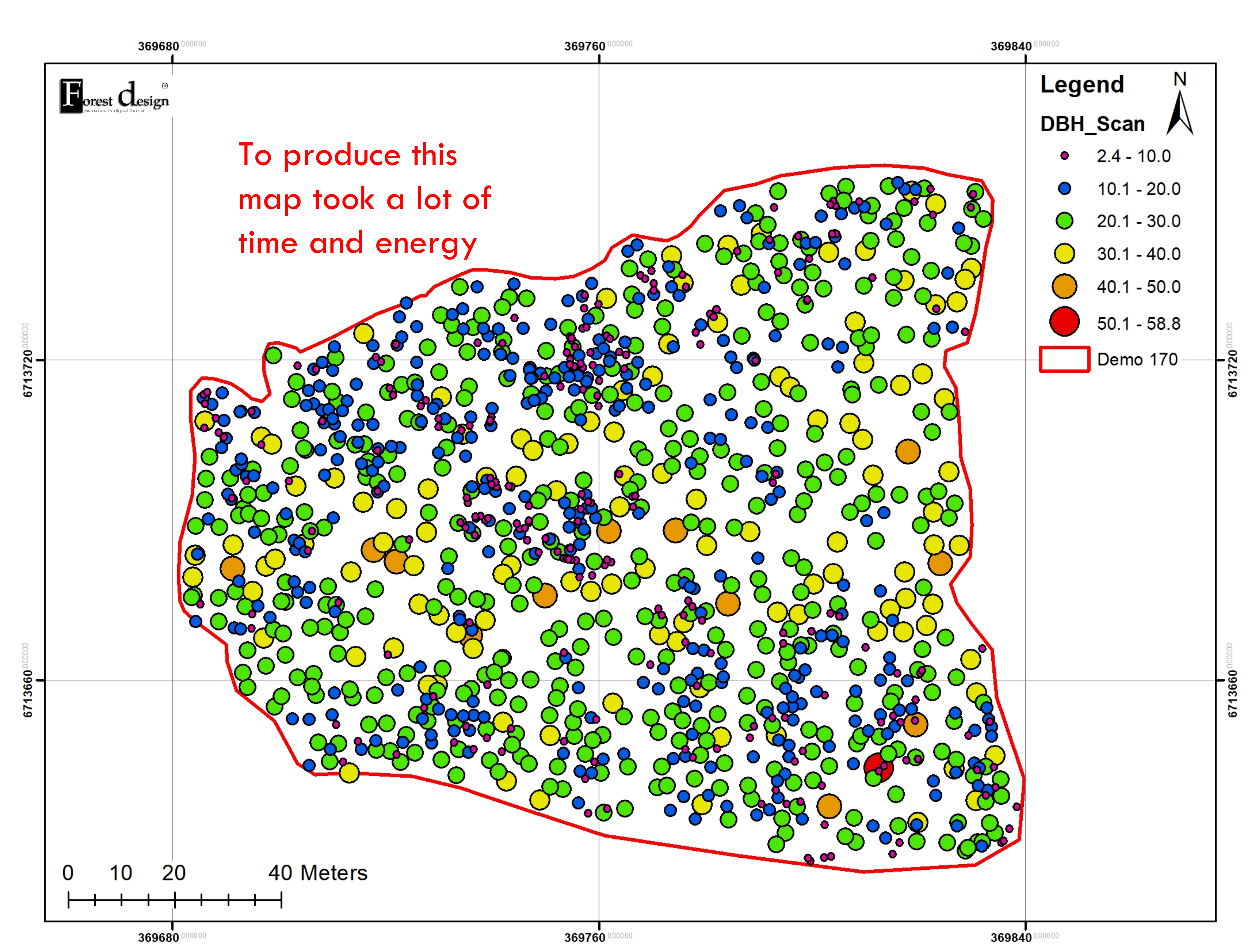
Scan – DBH and position



- Tree characteristics
- DBH computed by Least Square Regression
- X,Y,Z coordinate of tree position



Demo site 170



VIRTSILV PORTAL

AUTOMATIC TREE EXTRACTION AND VIRTUAL MEASUREMENTS FROM LIDAR IMAGERY

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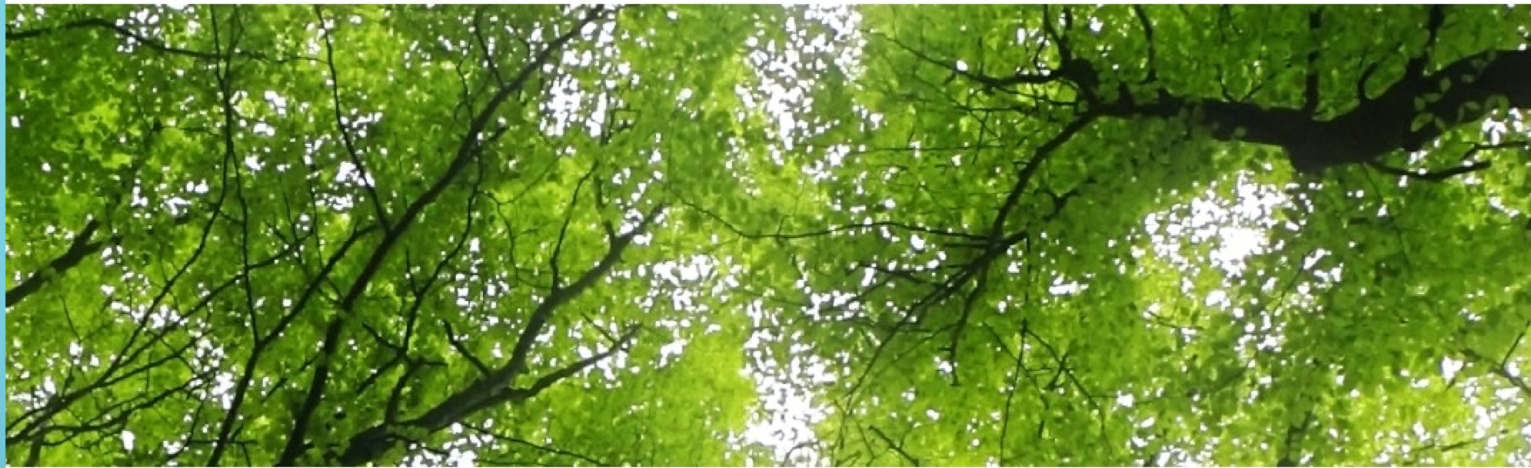
Abous VIRTSILV | Case Studies | Contact



About VIRTSILV

VIRTSILV is a software application for extracting data analytics about forest and individual trees, using LIDAR point cloud. It produces virtual models and measurements.
The technology is original and was developed and tested in Romania.

In situ data

Step 1 - Data collection

Collecting LIDAR data is the first and essential step. The methodology for data gathering is based on mobile LIDAR systems. The area of interest (AOI) must be a forest area with such dimensions and density of trees that the LIDAR system to be able to penetrate through it and collect information about individual trees. The shape of AOI can be arbitrary and the linear dimensions may vary in the order of tens of meters. The number of threes in the AOI, depending on their density, age, species, can be from some tens to a few hundred.

The LIDAR operator must obtain a full, all around, map, by going along the perimeter of the AOI and collecting data from different angles and positions. The density/distribution of the 3D virtual points must allow visual identification of individual trees, of their trunks, of the soil around them and, as much as possible, of their main branches and canopies.

The technology is original and **was developed and tested in Romania.**

- https://webgis-mapping.ro

DATA ENTRY

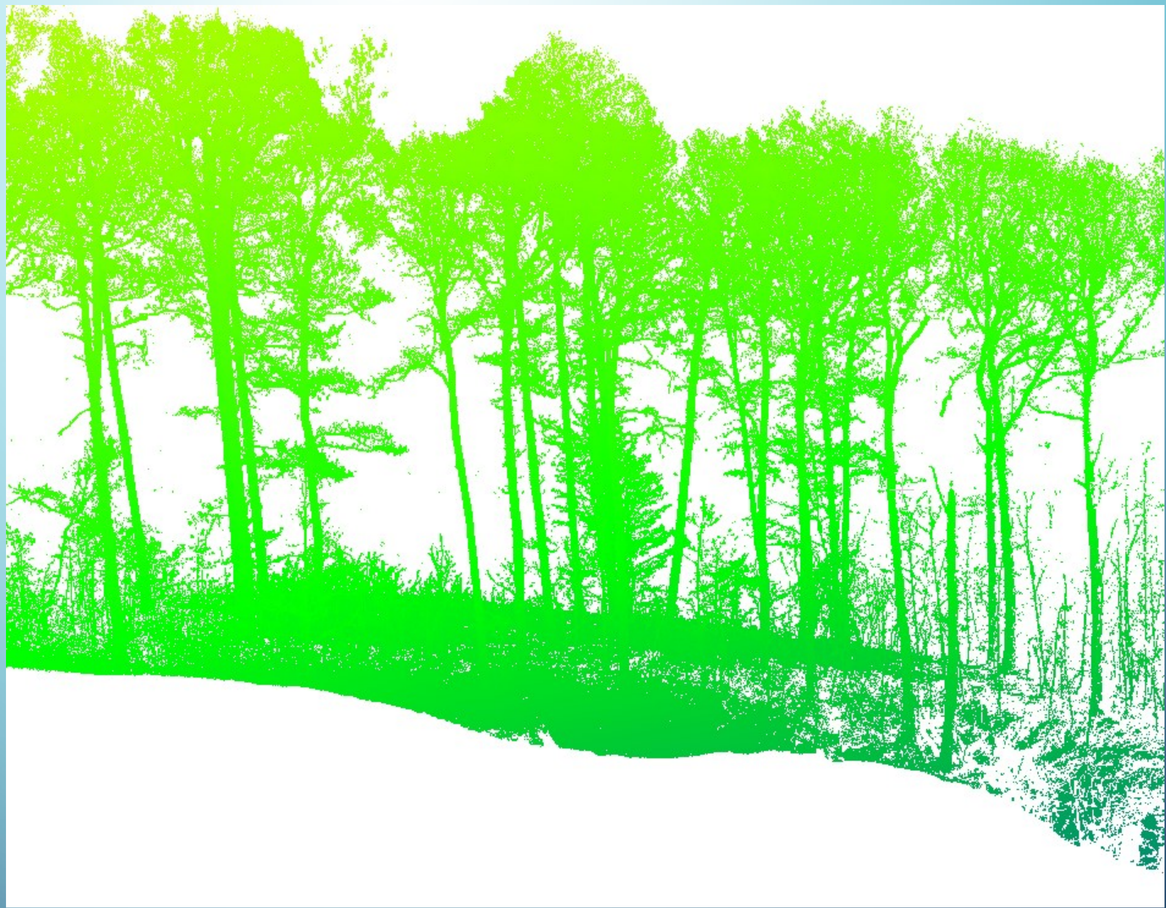


Figure 1. LIDAR data set. Raw Data Point Cloud

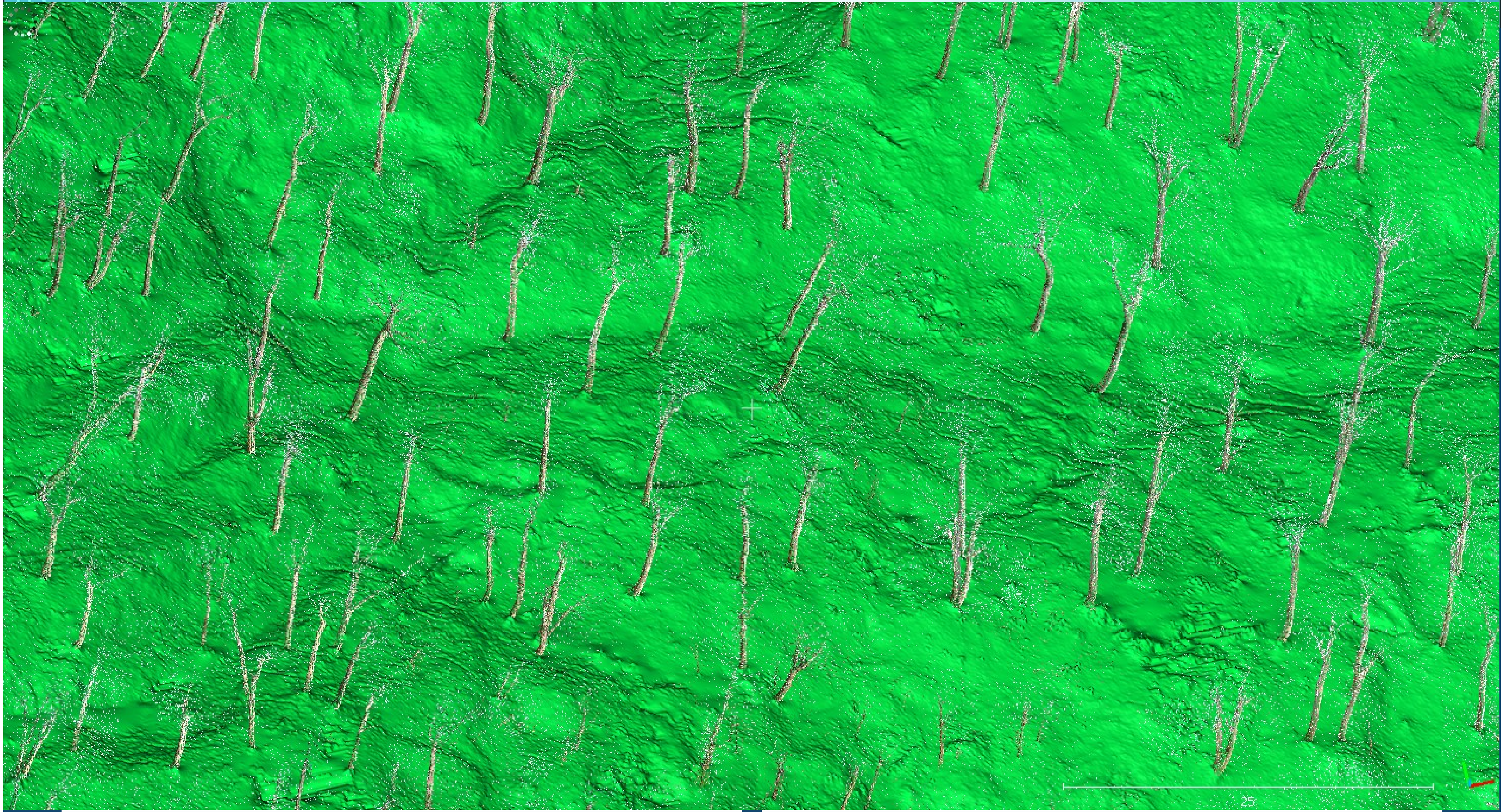
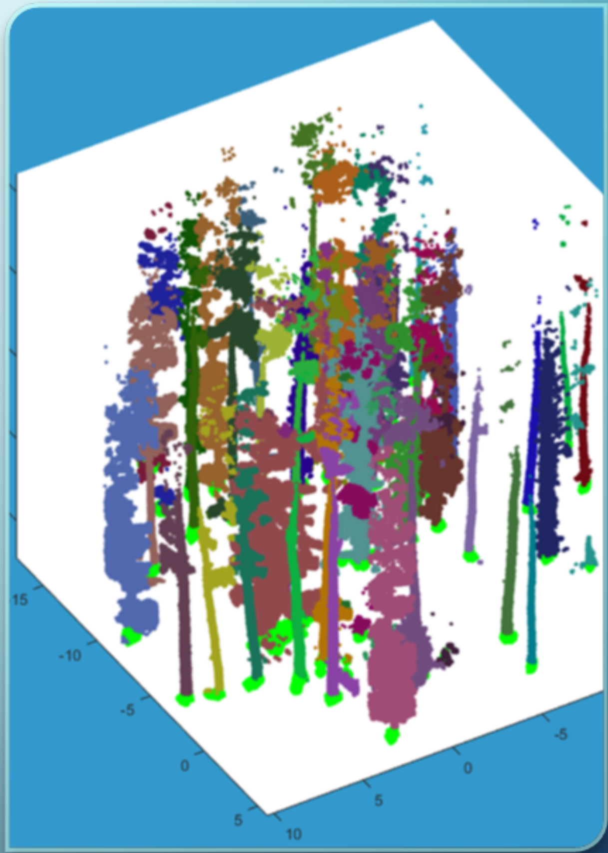


Figure 2. LIDAR data set. Ground and off-ground Birdseye view

PROCESSING CHAIN

Step 1.	Data ingestion and initial settings.
Step 2.	Extracting the ground level model,
Step 3.	Calibrating the system for machine learning
Step 4.	Extracting individual trees (segmentation)
Step 5.	Building mathematical models for each individual tree, based on in situ data and theoretical formulas (like diameter vs. height statistic tables and laws).
Step 6.	Exporting results in a local DB (geometry, position, volume, height for each tree), generating data analytics (number of trees, total trunk wood volume, average height, tree density etc.).



SETTINGS

All the software modules behind the process chain are customizable, by means of a series of parameters.

By carefully choosing the proper values for the parameters, one can maximize the performances of the system for any type of forest.

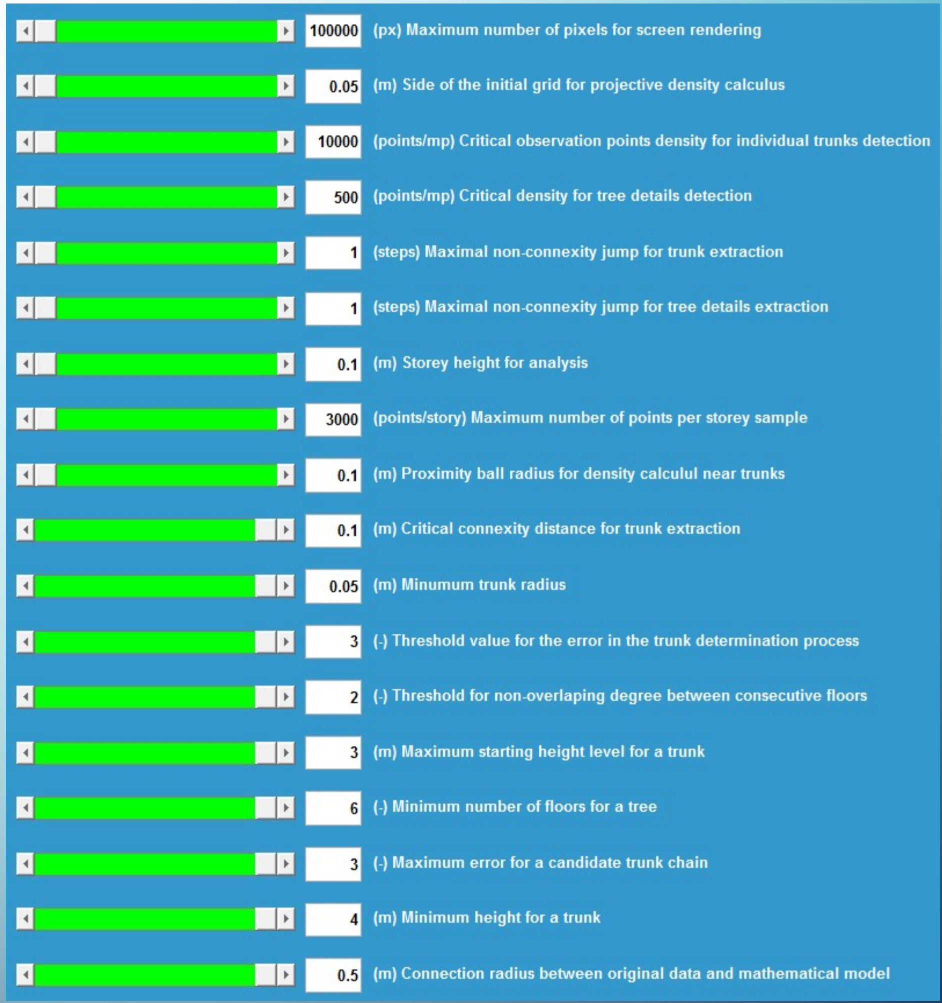
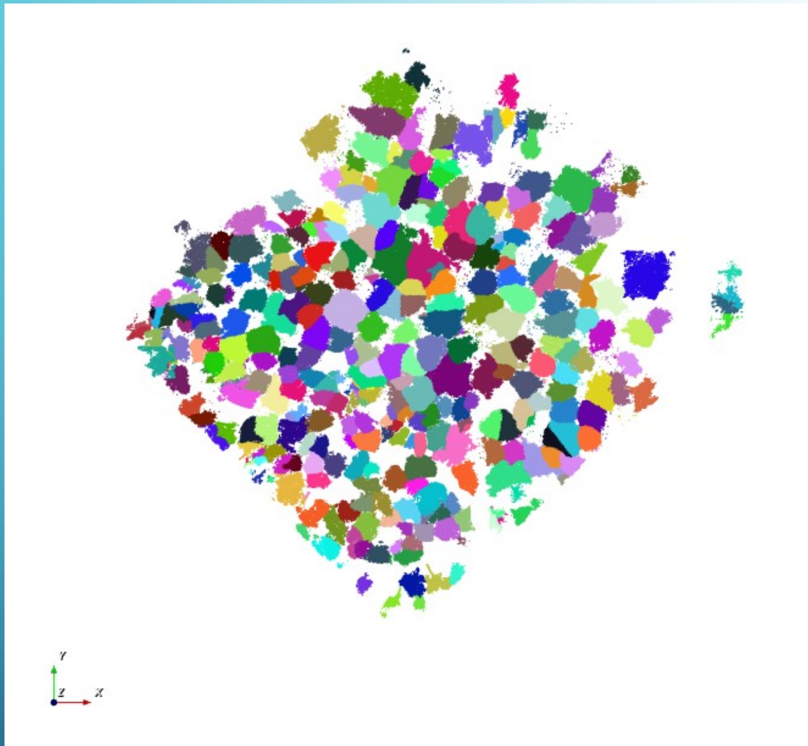
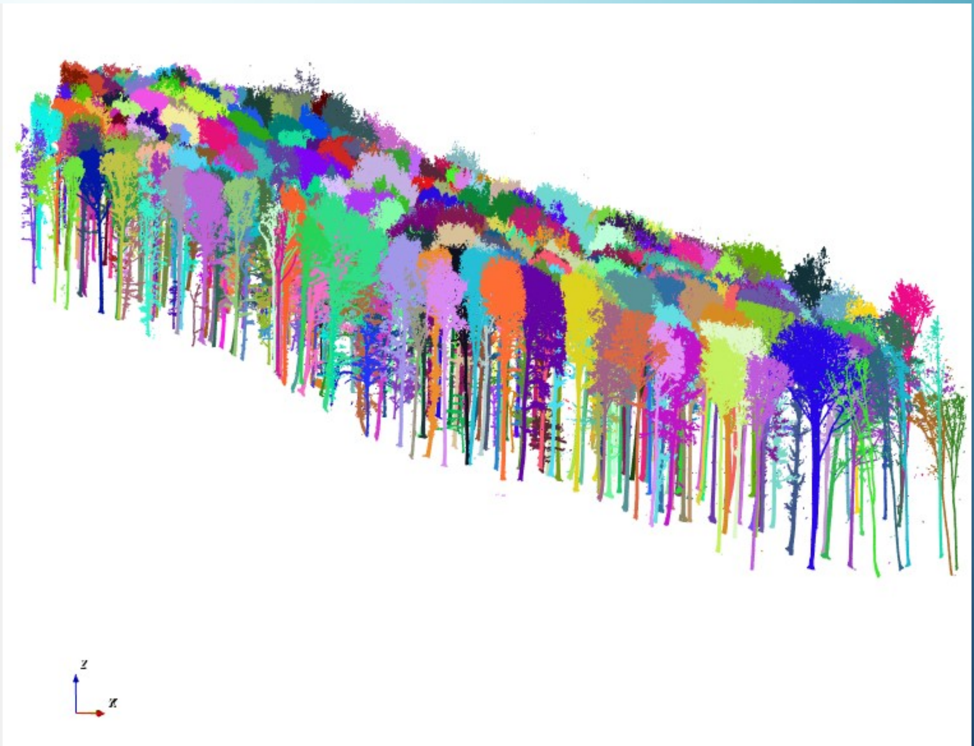


Figure 4. Main control panel, with 18 of the most important parameters of the system. The user must be well trained for a good usage of the panel. All the parameters are kept inside predefined intervals of variation.

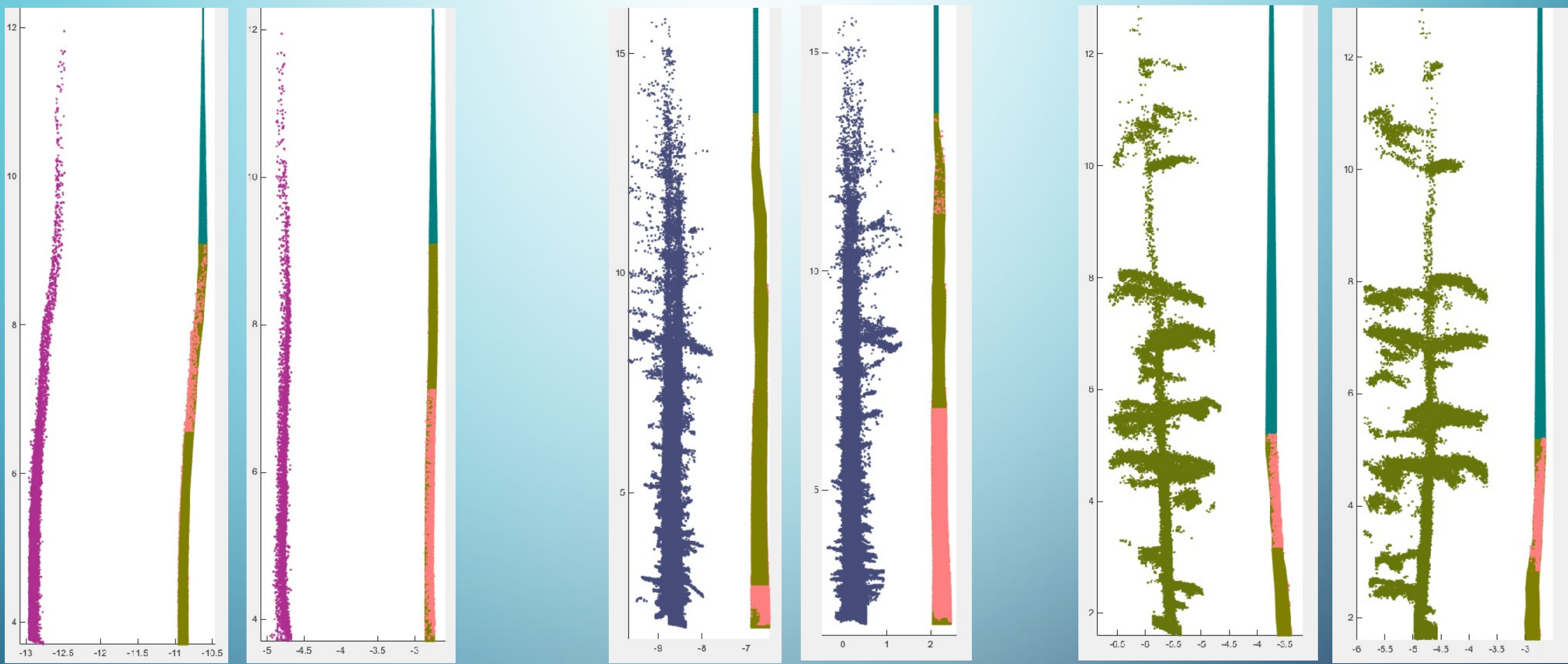
RESULTS





Raw tree extraction for the scene in Figure 1, using the initial data for representation. There were discovered 350 potential trees. The bright green spots from the bottom of the trunks mark the intersection with the ground level.

RECONSTRUCTING TREE CHARACTERISTICS - TRUNK

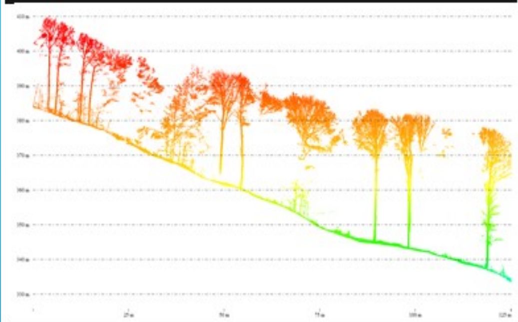


Comparison between raw tree extraction and the mathematical model of the same trunk.
LEFT: XZ view, RIGHT: YZ view.

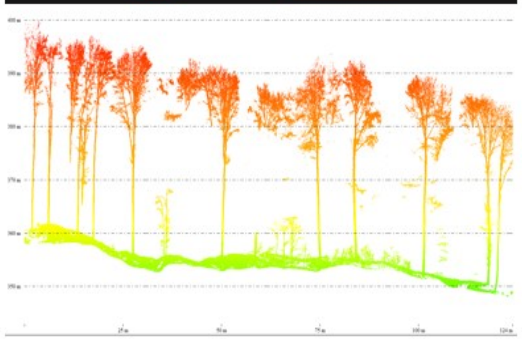
RECONSTRUCTING TREE CHARACTERISTICS TRUNK AND BRANCHES

FROM TREE TO STAND LEVEL – PORTAL REPORTS

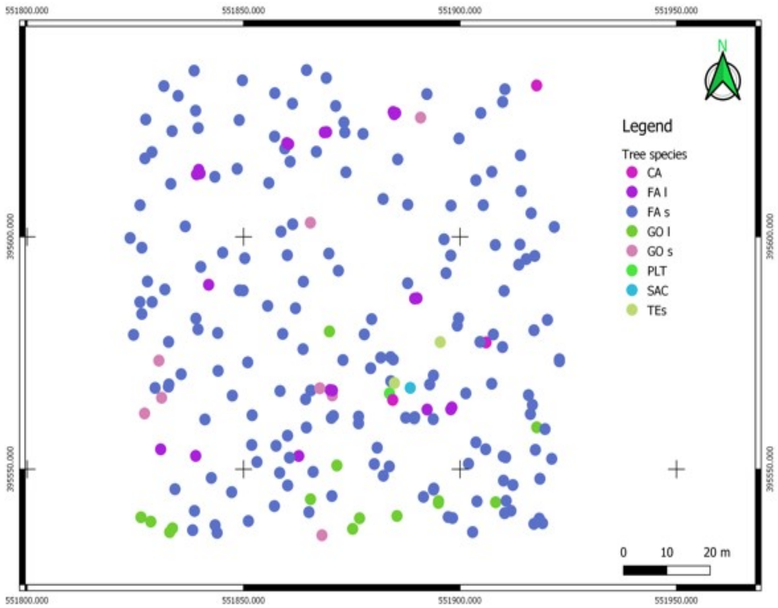
North – South Transect



East – West Transect



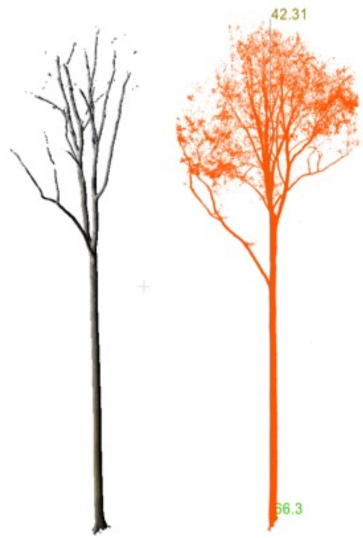
Quality class	Volume%
1	56.76%
2	34.38%
3	7.54%
4	1.33%

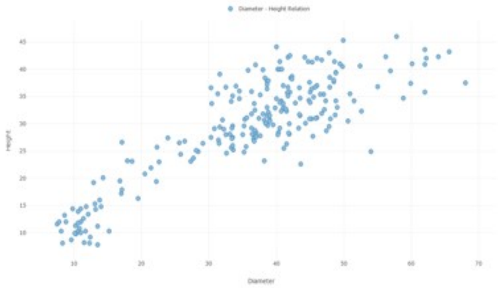


Results

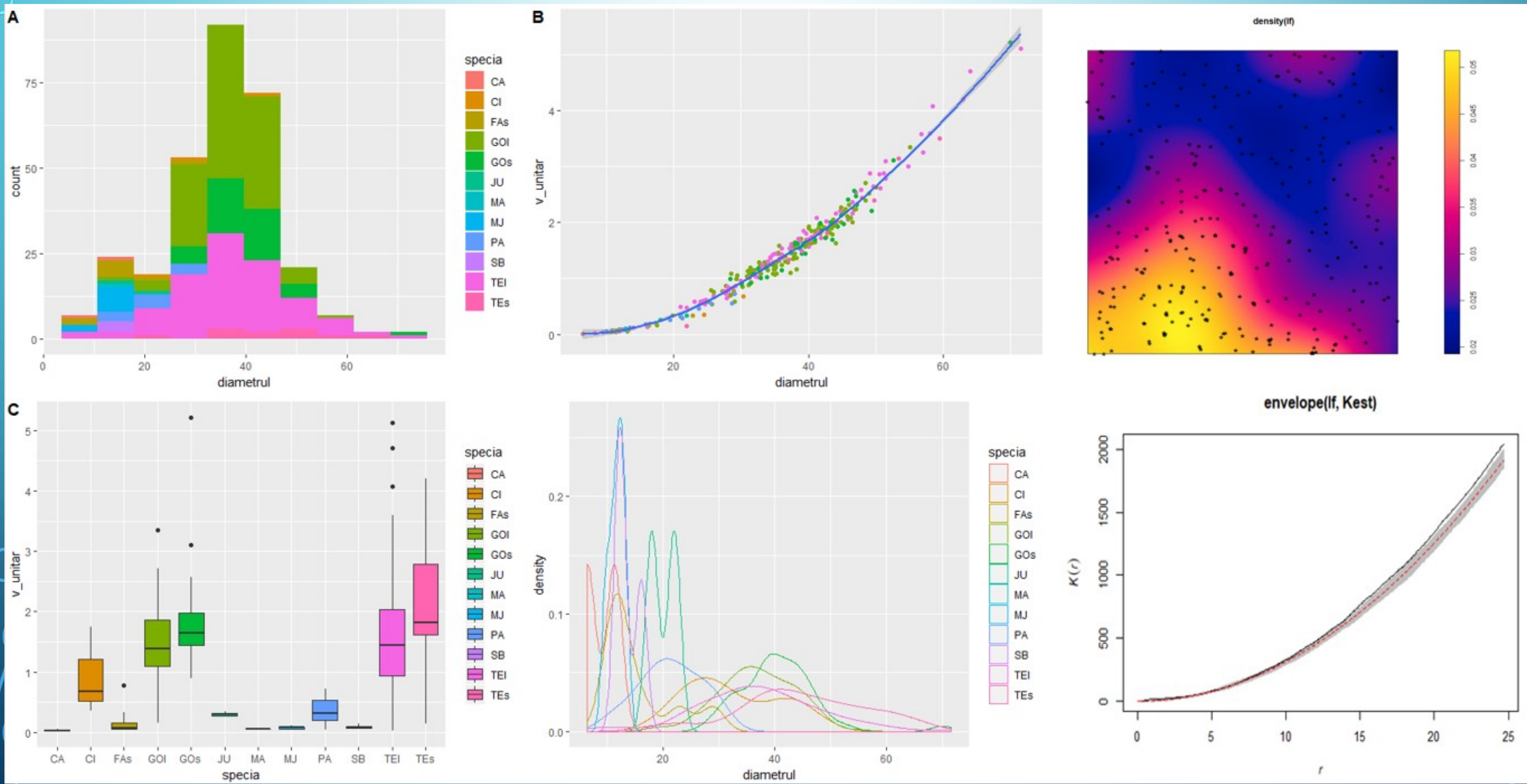
N (stems/ha)	225
Basal area (m2/ha)	25.92
Volume (m3/ha)	452.9
Average Diameter (cm)	45.5
Average Height (m)	35.3

Single Tree 3D Model





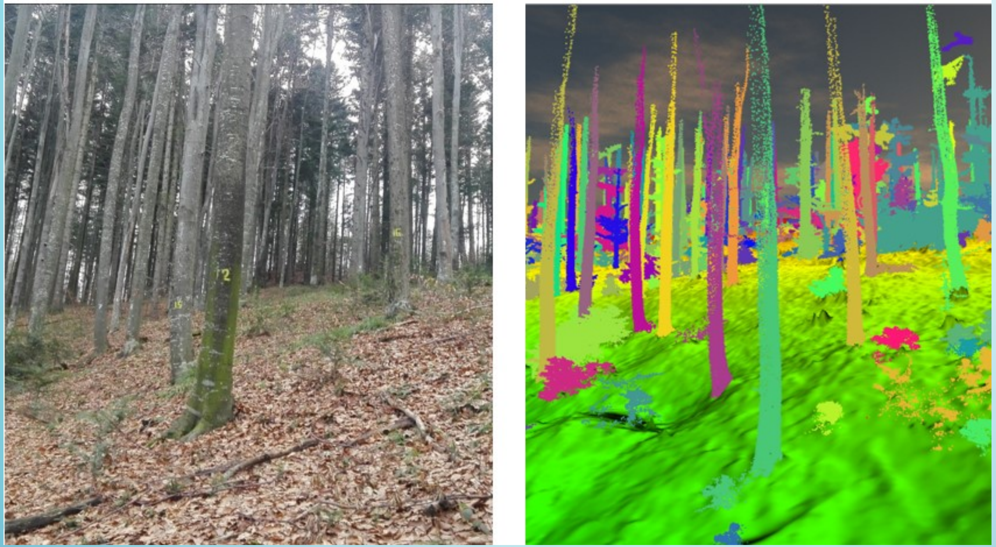
FROM TREE TO STAND LEVEL – PORTAL REPORTS



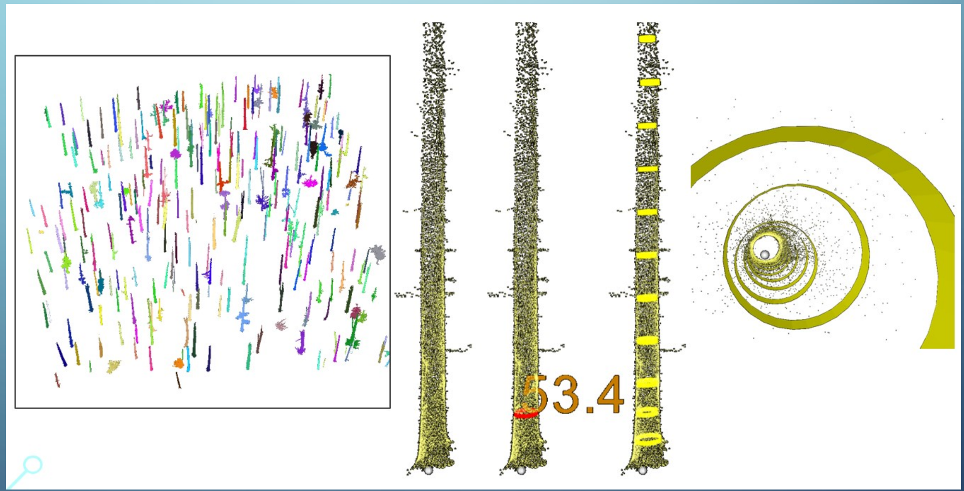
NEW DEVELOPMENT

CONNECTING WITH SATELLITE DATA

CONNECTING TO SATELLITE DATA

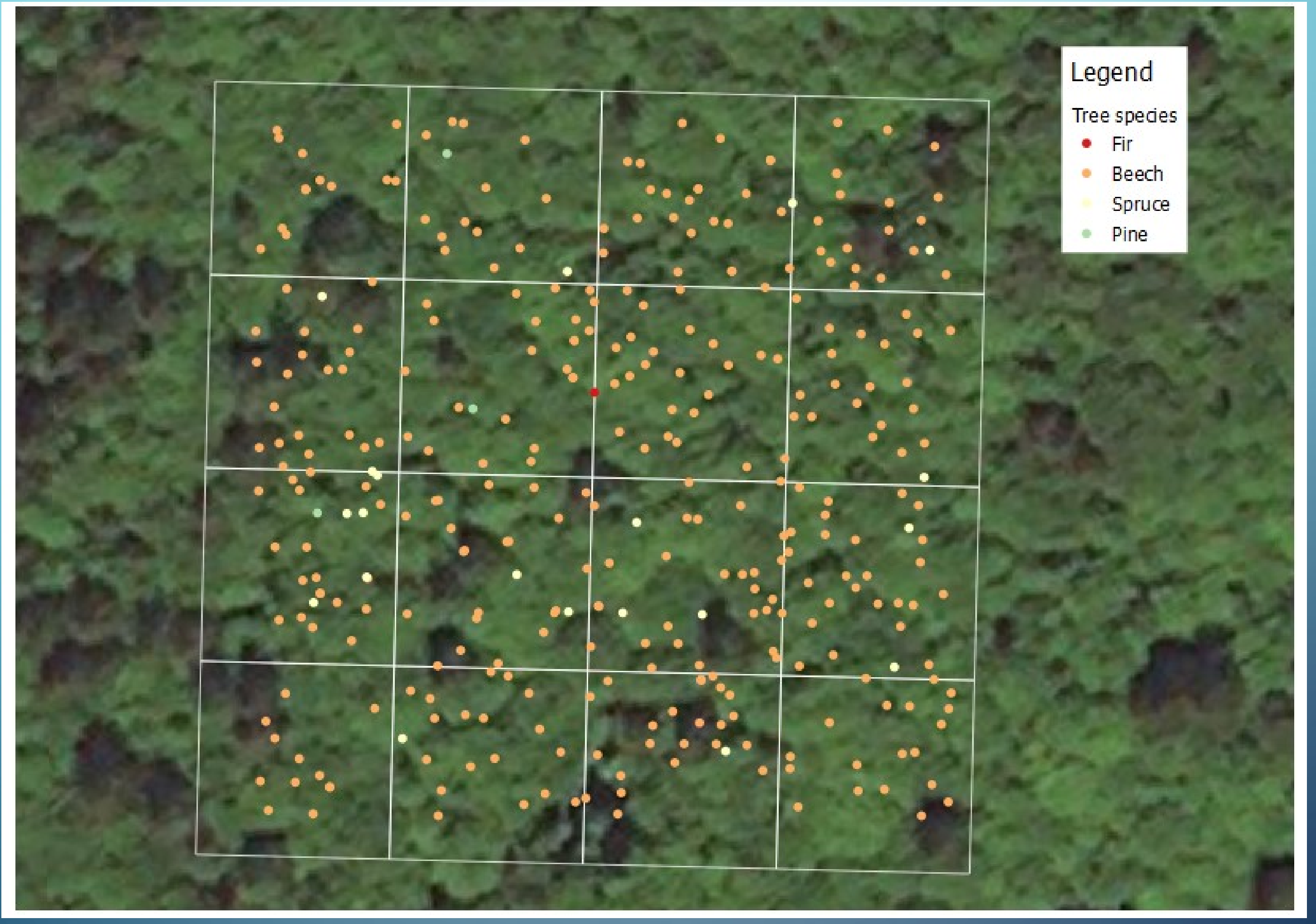


Trees with unique ID in the field (left) and the corresponding point clouds (right) generated with TLS (Terrestrial Laser Scanner)



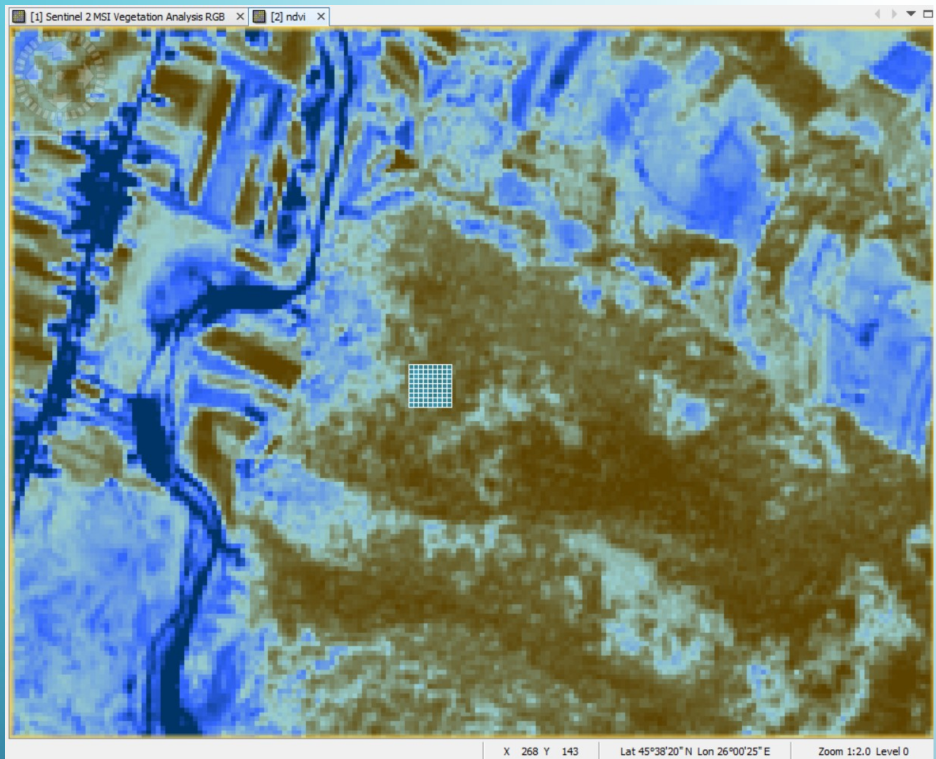
Individual tree point clouds and accurate measurement of location, DBH and tree stem curvature

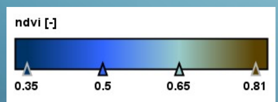
CONNECTING TO SATELLITE DATA

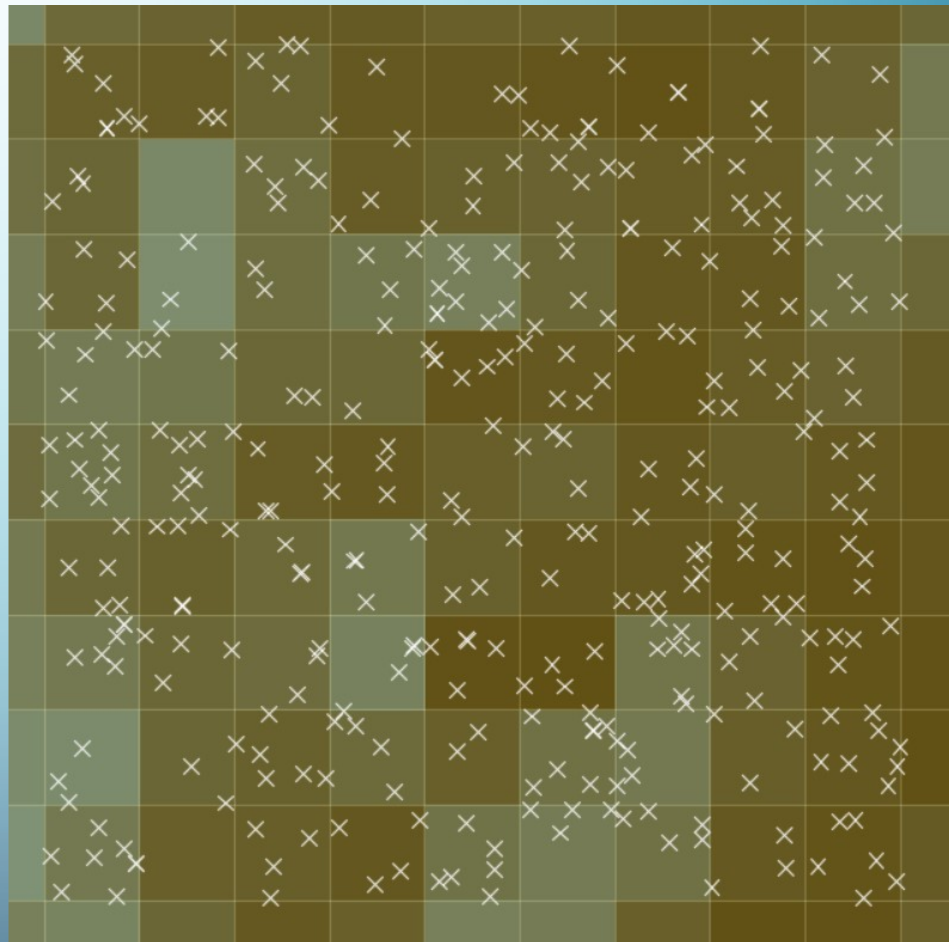


Tree position on VHR satellite image (WorldView3) – source Google Satellite

CONNECTING TO SATELLITE DATA

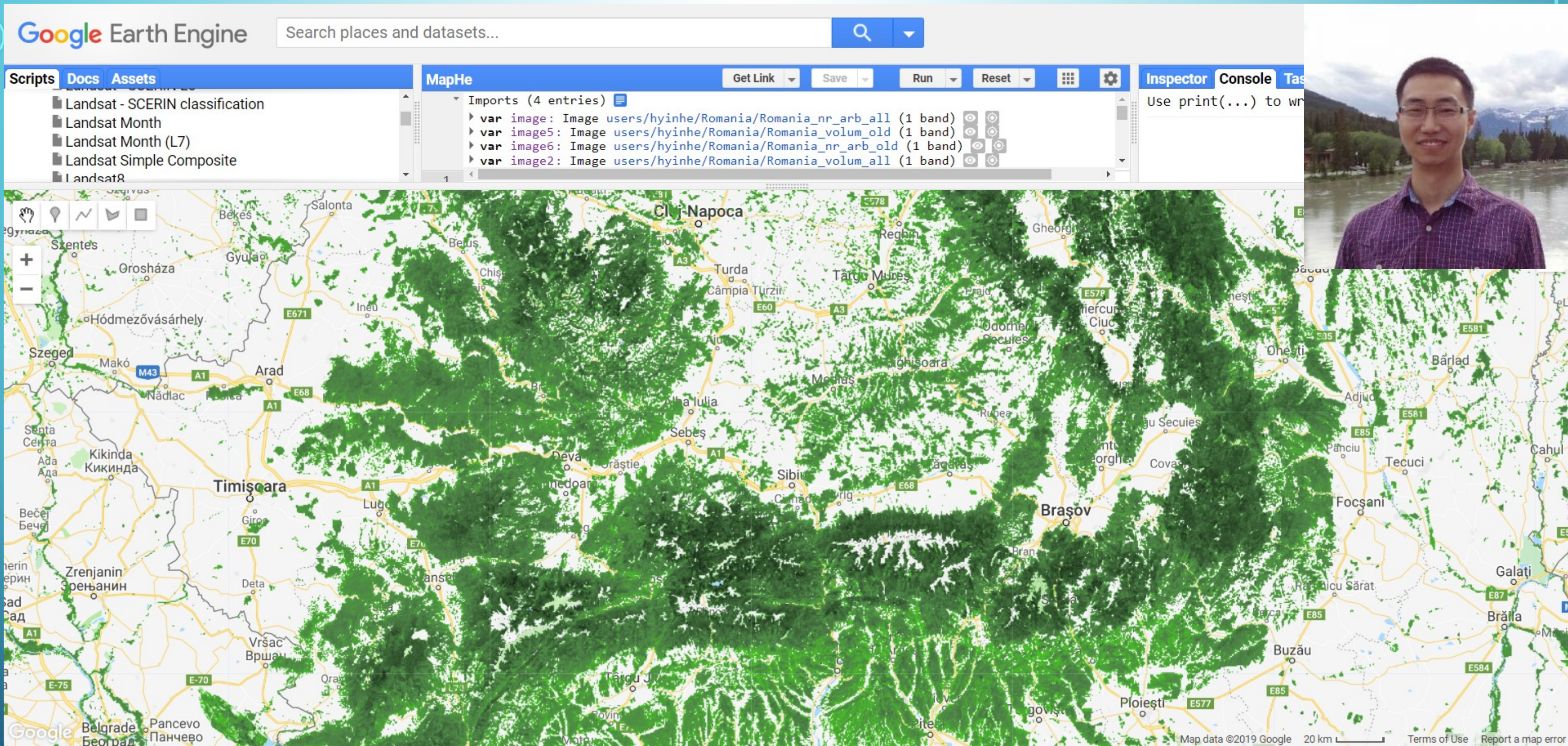






Extrapolating data from Terrestrial Laser Scanner using RS data

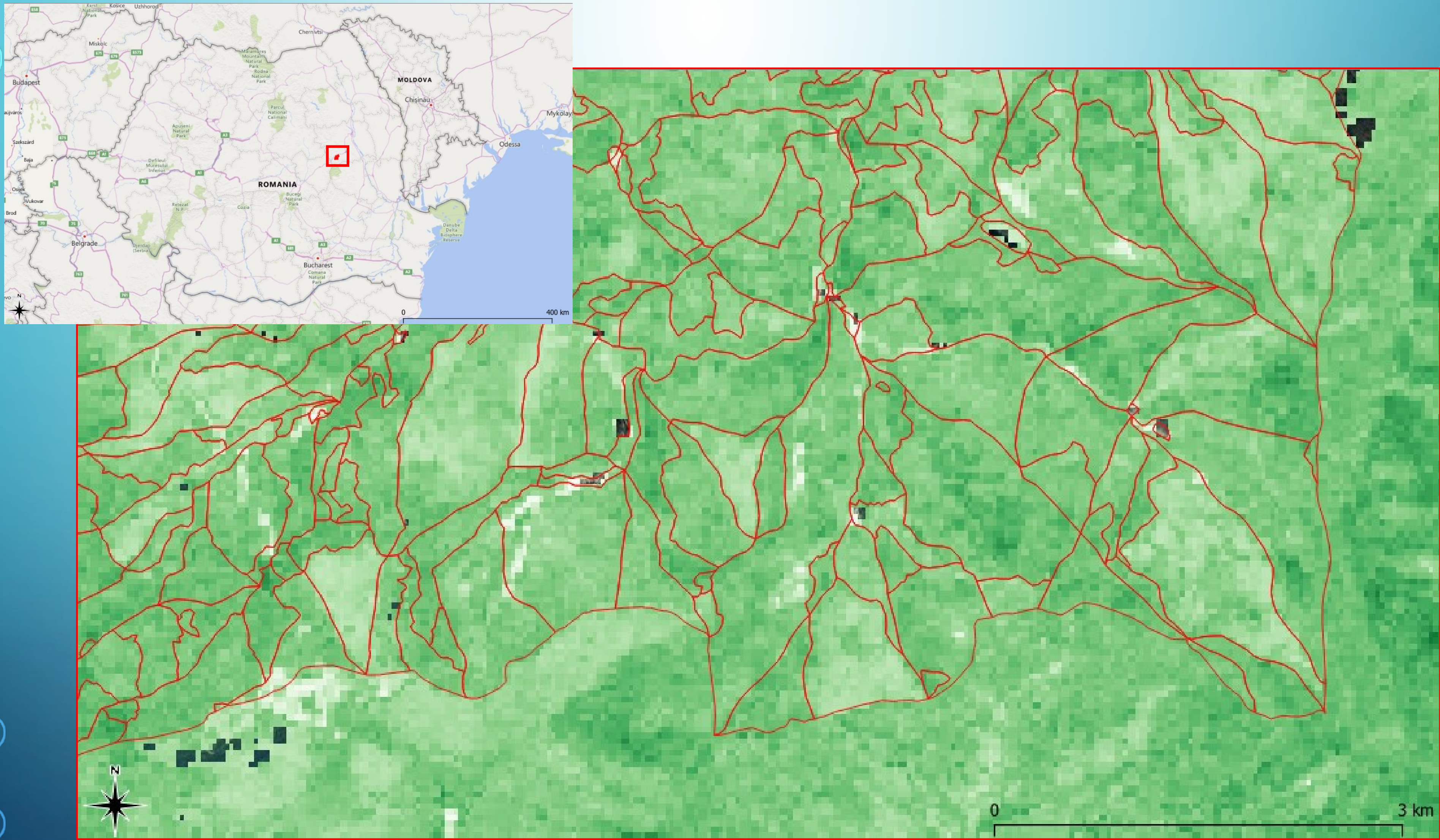
FIRST STEPS IN BUILDING THE SERVICE
ESTIMATING THE STANDING VOLUME AT PIXEL LEVEL
(HE YIN – UNIVERSITY OF WISCONSIN)



Extrapolating data from Terrestrial Laser Scanner using RS data

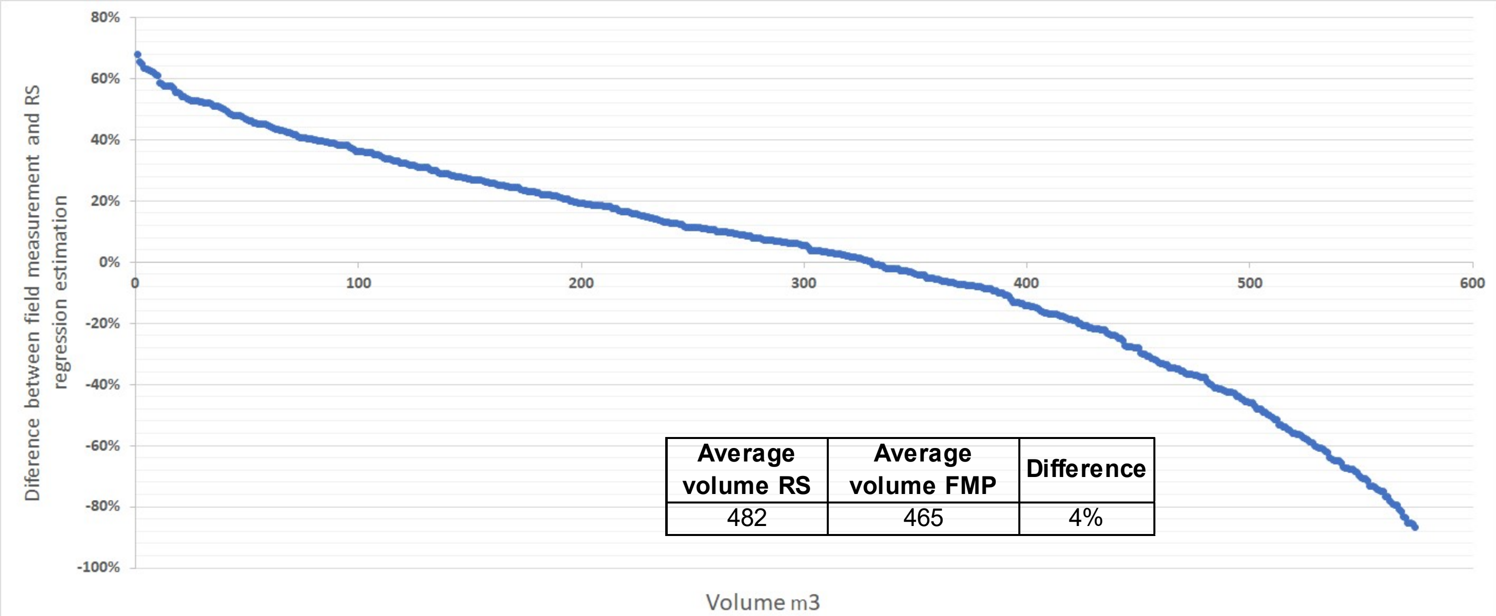
Classification was performed by using a pixel-based supervised random forest (RF) machine learning algorithm (MLA) executed on the Google Earth Engine (GEE) cloud computing platform

COMPARING WITH THE FIELD DATA – FMP1

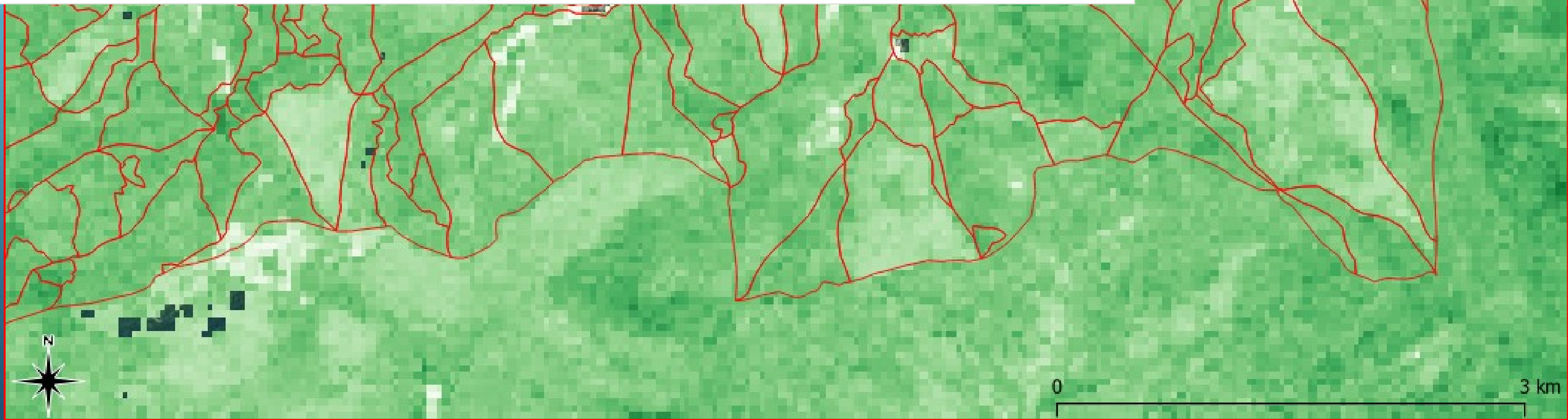


Standing tree volume map overlap with forest compartment map

COMPARING WITH THE FIELD DATA – FMP1

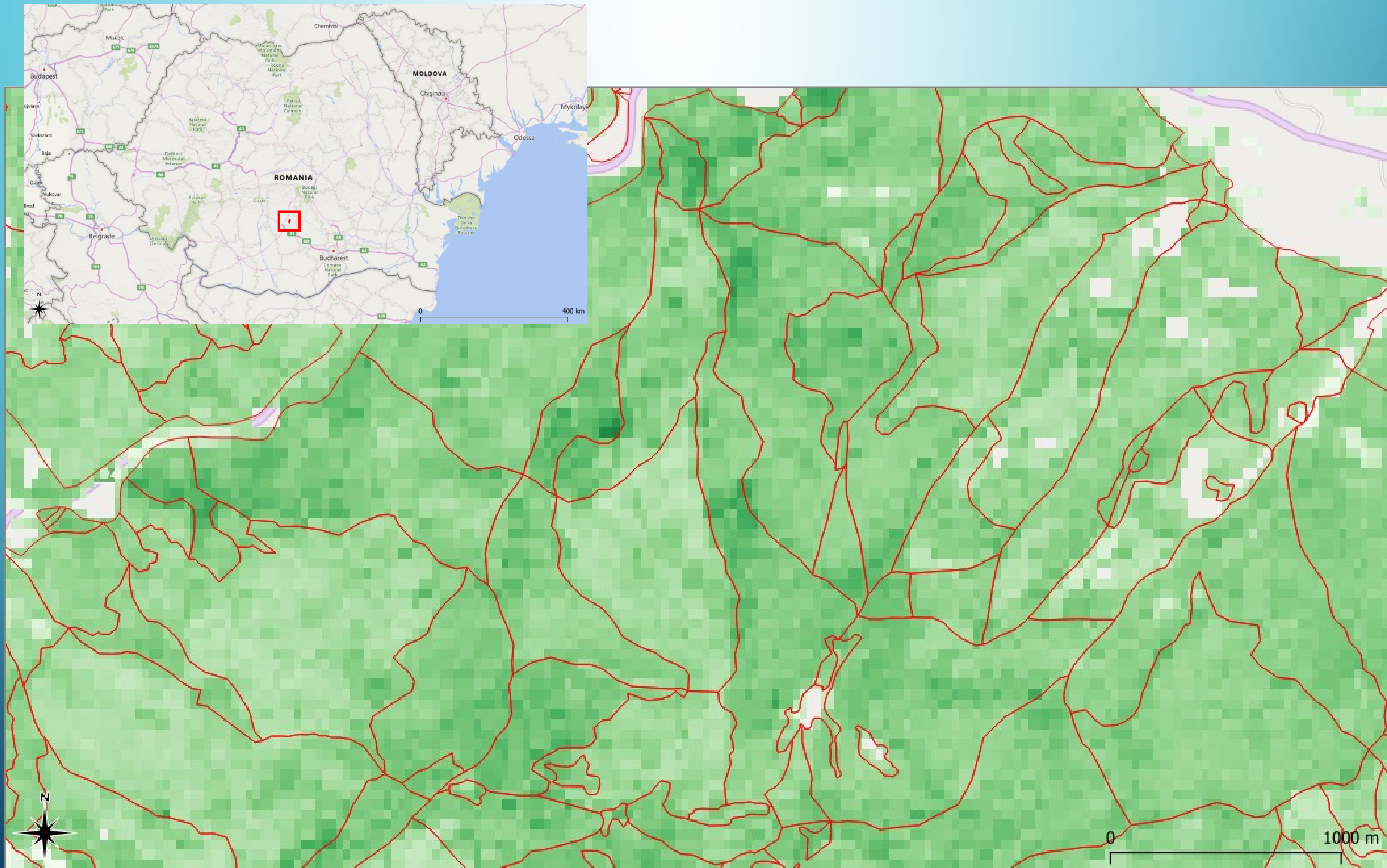


Average volume RS	Average volume FMP	Difference
482	465	4%



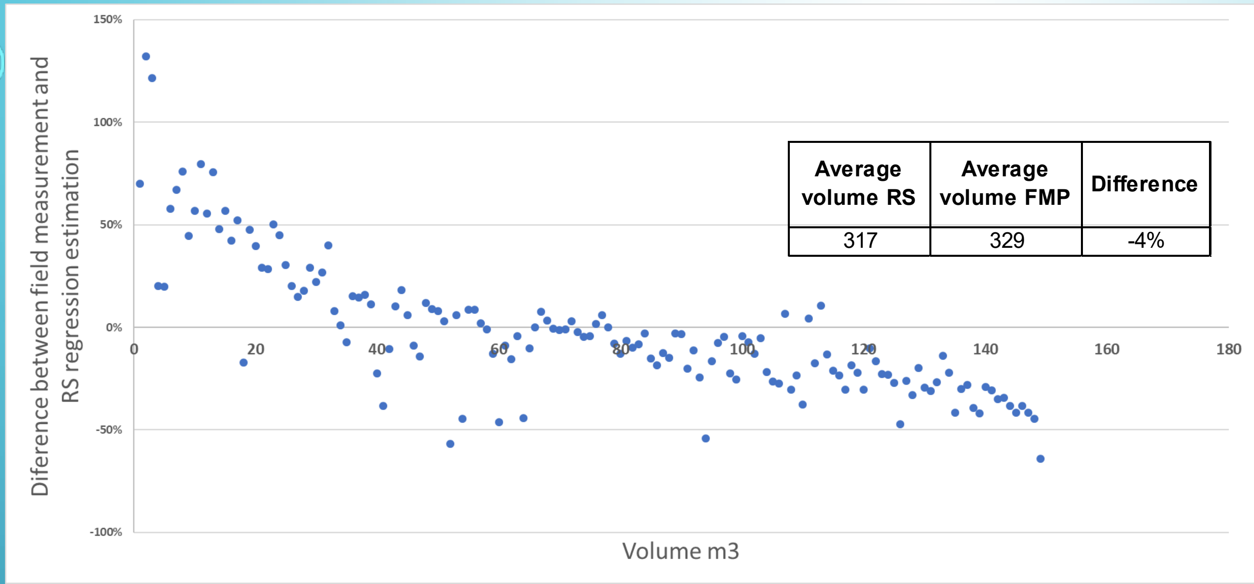
Standing tree volume map overlap with forest compartment map

COMPARING WITH THE FIELD DATA – FMP2

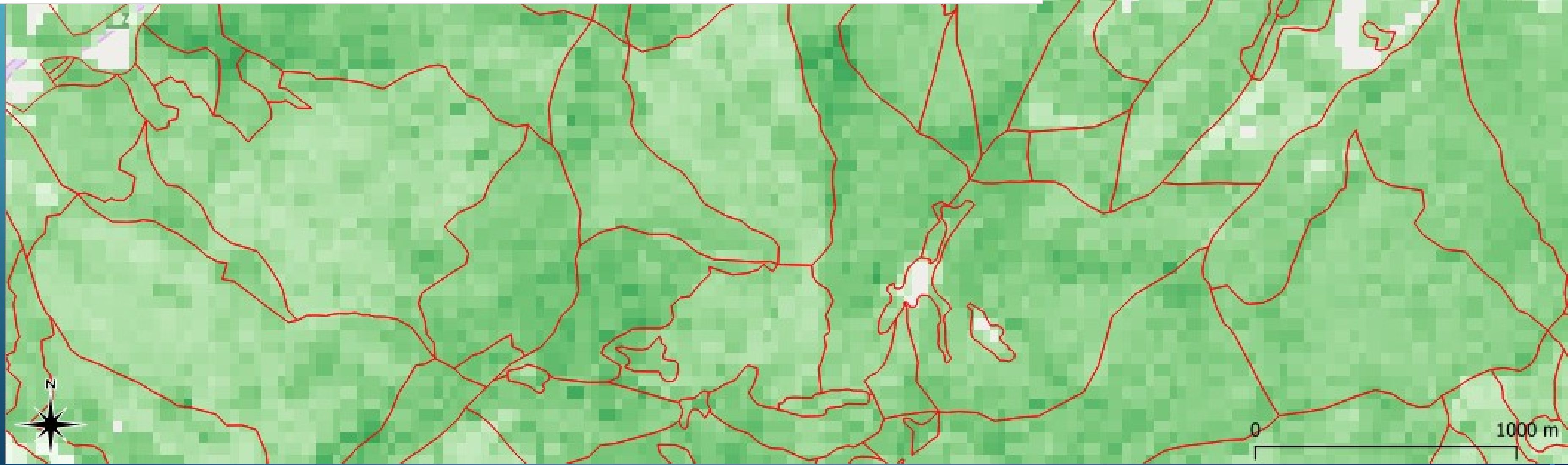


Standing tree volume map overlap with forest compartment map

COMPARING WITH THE FIELD DATA – FMP2

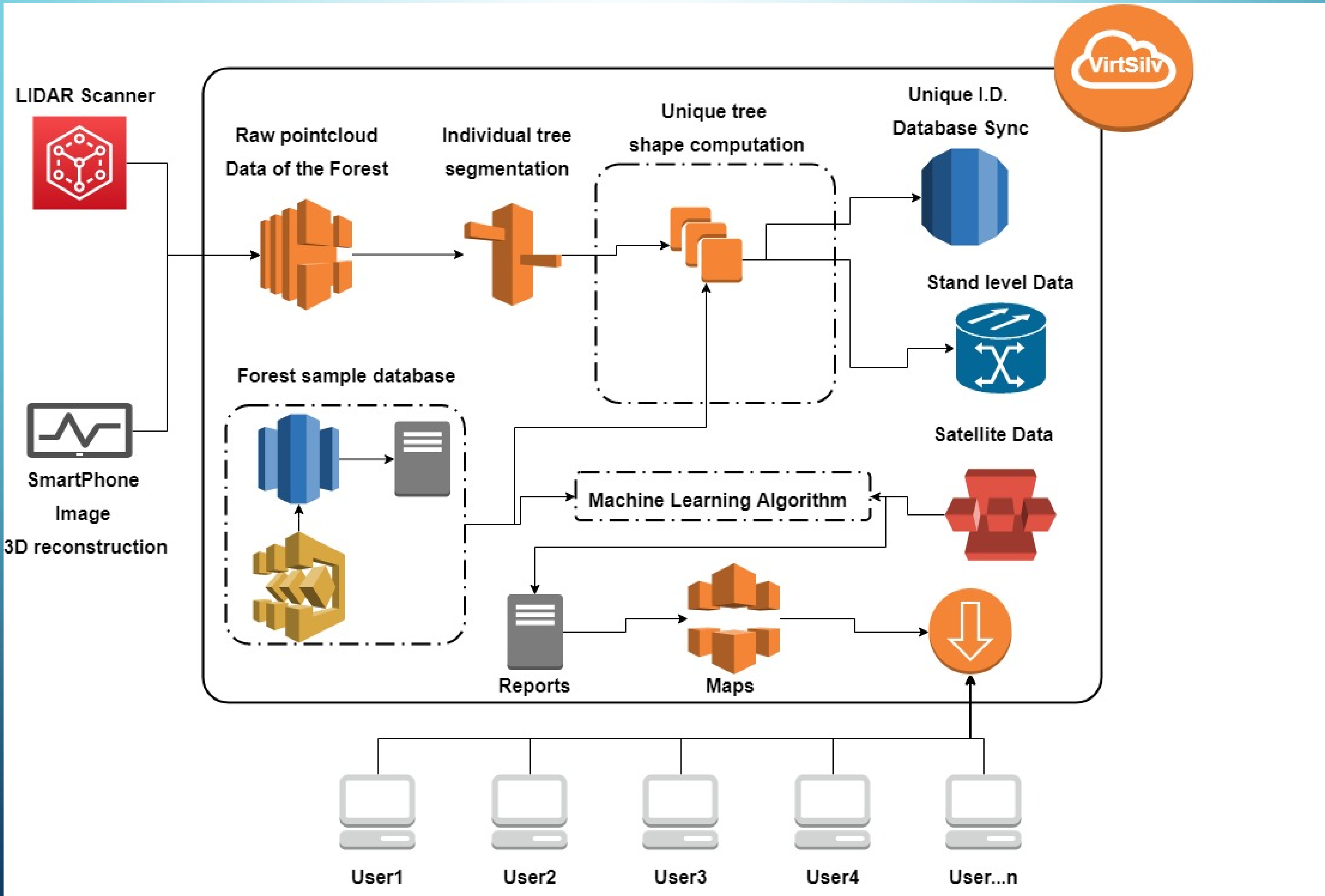


Average volume RS	Average volume FMP	Difference
317	329	-4%



Standing tree volume map overlap with forest compartment map

CONCLUSION



LIDAR Scanner
SmartPhone
Image
3D reconstruction
VirtSilv
Raw pointcloud
Data of the Forest
Individual tree
segmentation
Unique tree
shape computation
Unique I.D.
Database Sync
Stand level Data
Forest sample database
Satellite Data
Machine Learning Algorithm
Reports
Maps
User1
User2
User3
User4
User...n

THANK YOU FOR YOUR ATTENTION!