Forest inventory with Terrestrial LiDAR: what about Hand-Held Mobile LiDAR?

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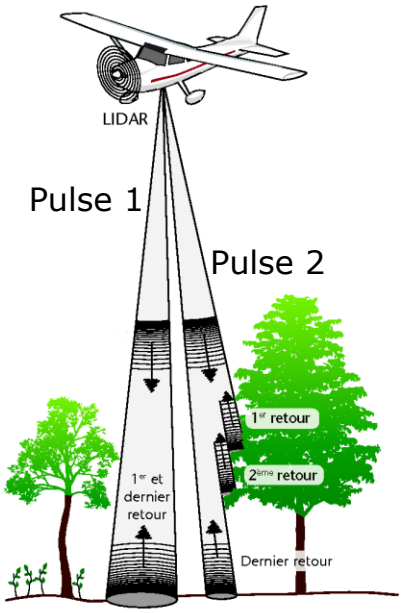
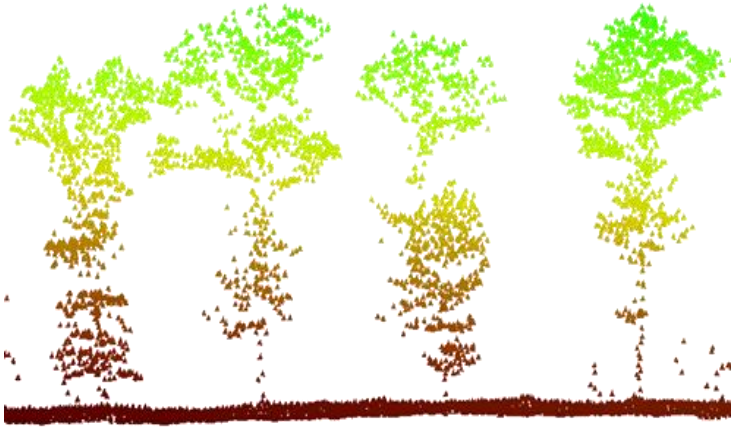
Gembloux Agro-Bio Tech
Université de Liège

WAGENINGEN UR
For quality of life

Introduction

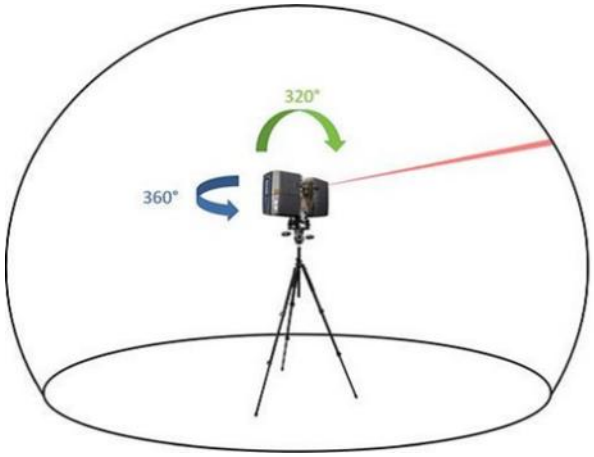
- 3 types of laser scanning systems:
  - **Airborne Laser Scanning (ALS)**

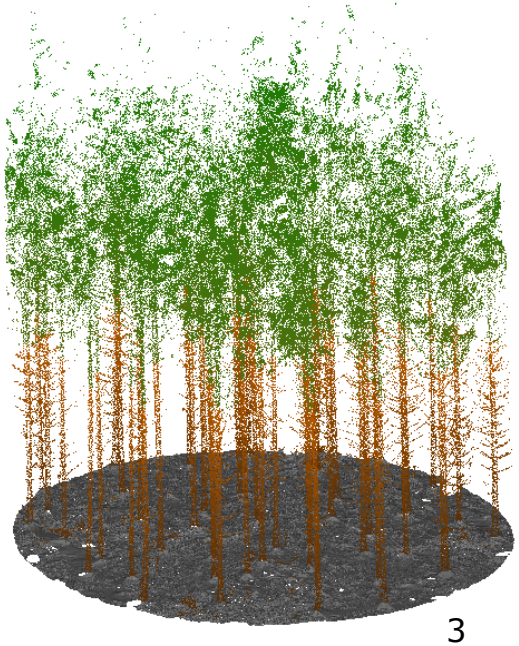




Introduction

- 3 types of laser scanning systems:
  - Airborne Laser Scanning (ALS)
  - **Terrestrial Laser scanning (TLS)**





Introduction

- 3 types of laser scanning systems:
  - Airborne Laser Scanning (ALS)
  - Terrestrial Laser scanning (TLS)
  - **Mobile Laser Scanning (MLS)**

http://en.wikipedia.org/wiki/Laser_scanning

http://www.soue.org.uk/souenews/issue4/mobilerobots.html

Introduction

- Mobile Laser Scanning
  - **Personal Laser Scanning (PLS)**

Kukko et al., 2012

Liang et al., 2014

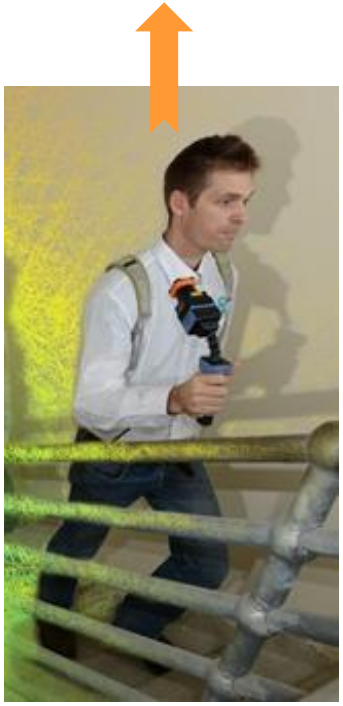
Introduction

- Mobile Laser Scanning
  - Personal Laser Scanning (PLS):

Hand-Held
Mobile LiDAR

Kukko et al., 2012

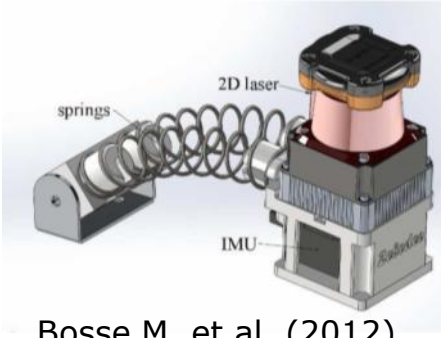
Liang et al., 2014



Materials

FARO FOCUS 3D

ZEB1



Bosse M. et al. (2012)

Materials

	FARO Focus 3D 120	ZEB1
Accuracy @ 10m	2 mm	3 cm
Range	120 m	30 m
Beam divergence	0.19 mrad	~ 10-14 mrad
Weight	5 kg	700 g
Approx.price	~ 41 000 €	~ 22 000€

0.4 €/credits

Methods

Study sites

10

TL6

Plot	10	TL6	31	TL4
Stand type	Broadleaves	Broadleaves	Conifers	Conifers
Topo	Bowl	Flat	Steep	Flat
Nr of trees	12	39	29	42
Density (trees/ha)	170	552	410	594
G (m^2/ha)	29	31	26	46

31

TL4

Methods
Study sites

10

TL6

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TL4

Methods
Site study

10

TL6

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Topo	Bowl	Flat	Steep	Flat
Nr of trees		=122		
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TL4

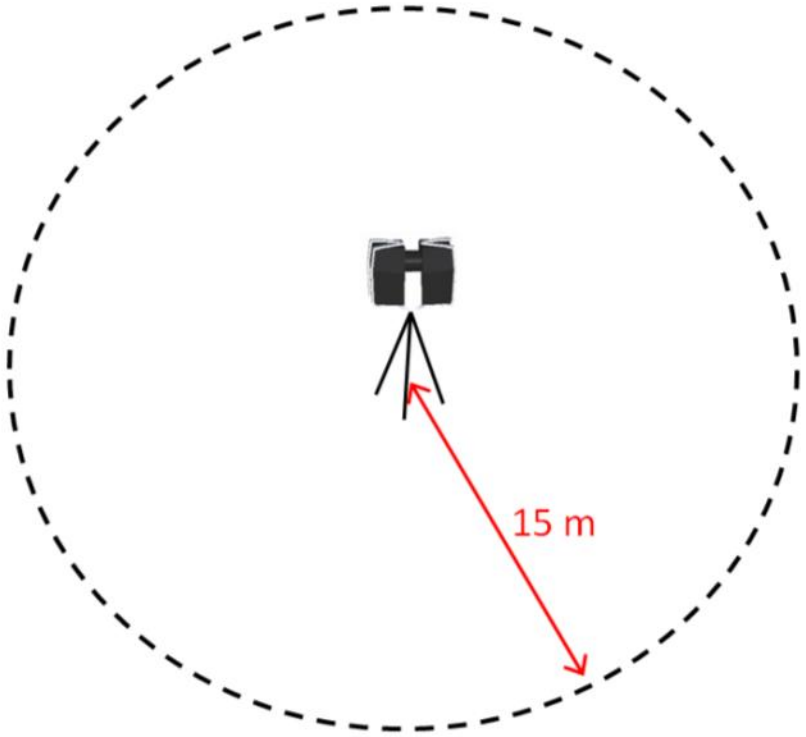
Methods
Field data acquisition

4 plots:

- Circular plots of **15 m of radius**
- DBH measurement of **trees > 10 cm** with **tape**
- Position of trees (azimuth and distance)
- **FARO Scans** (TLS)
- **ZEB1 Scan** (PLS-HHMLS)

Methods
Field data acqusition

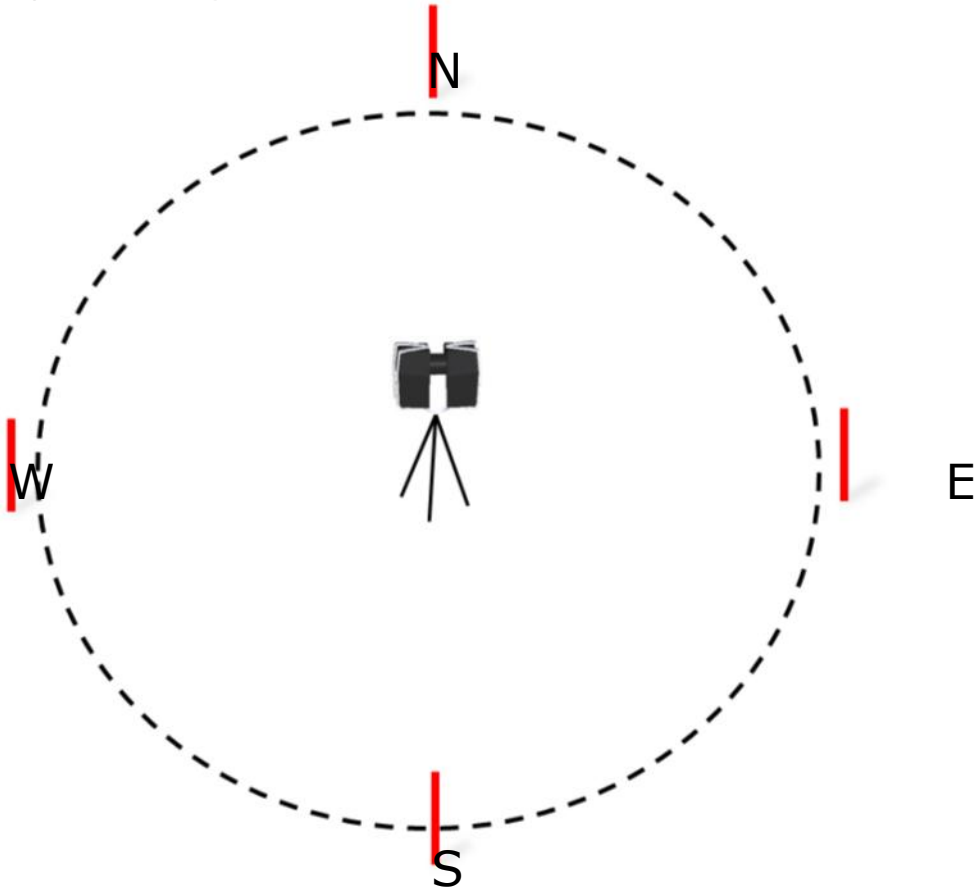
1st TLS method: Single scan in the center



Methods
Field data acqusition

2nd TLS method: multi-scan (5 scans)

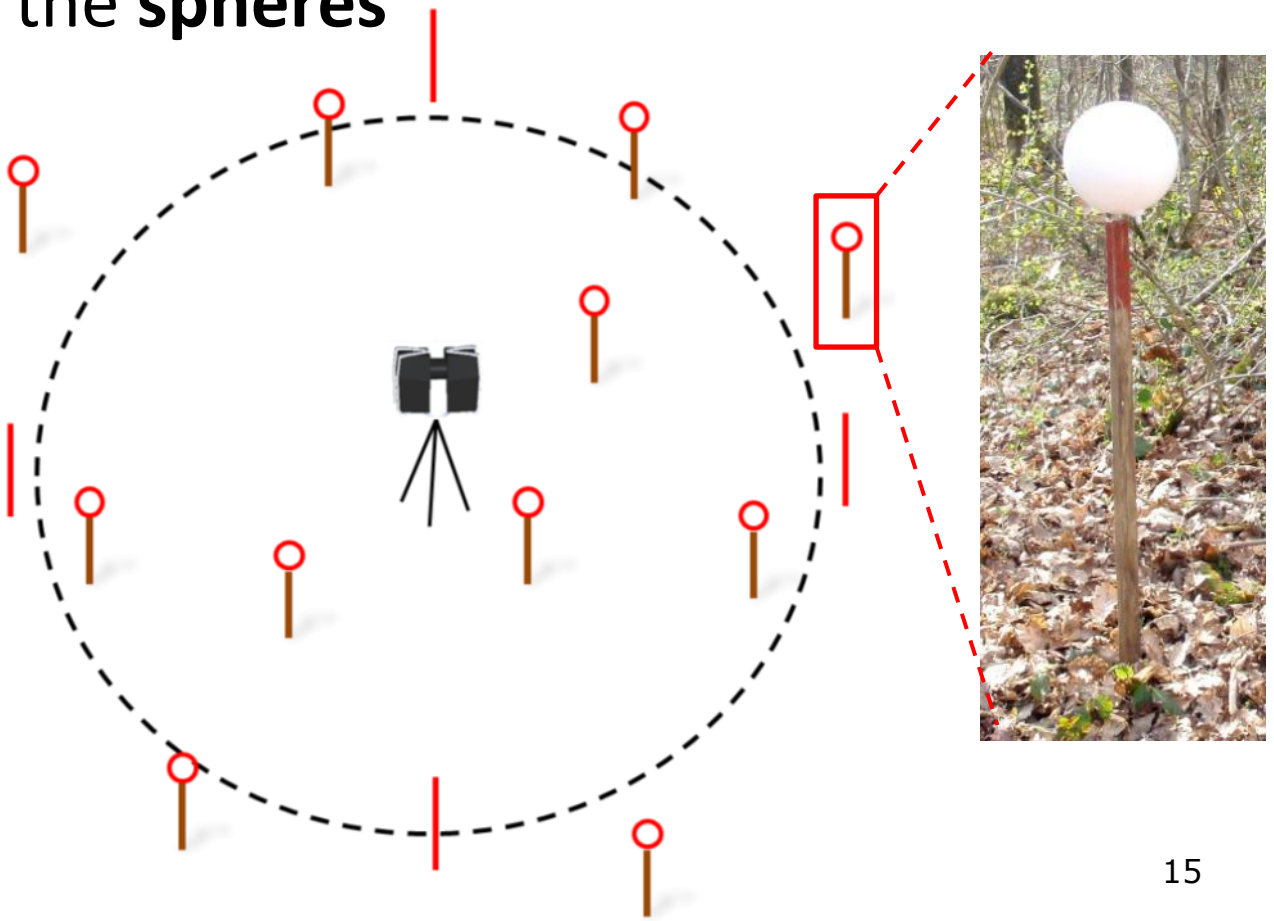
- Setting up the **position of the scans**



Methods
Field data acqusition

2nd TLS method: multi-scan (5 scans)

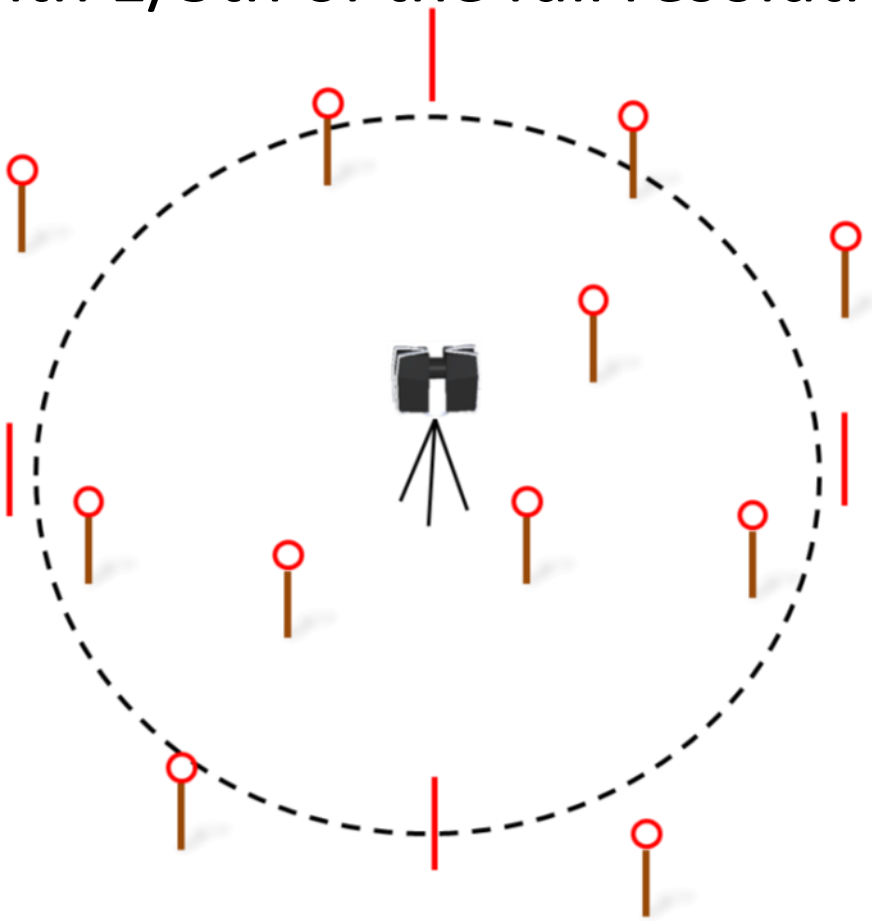
- Setting up the **spheres**



Methods
Field data acqusition

2nd TLS method: multi-scan (5 scans)

- Scans with 1/5th of the full resolution



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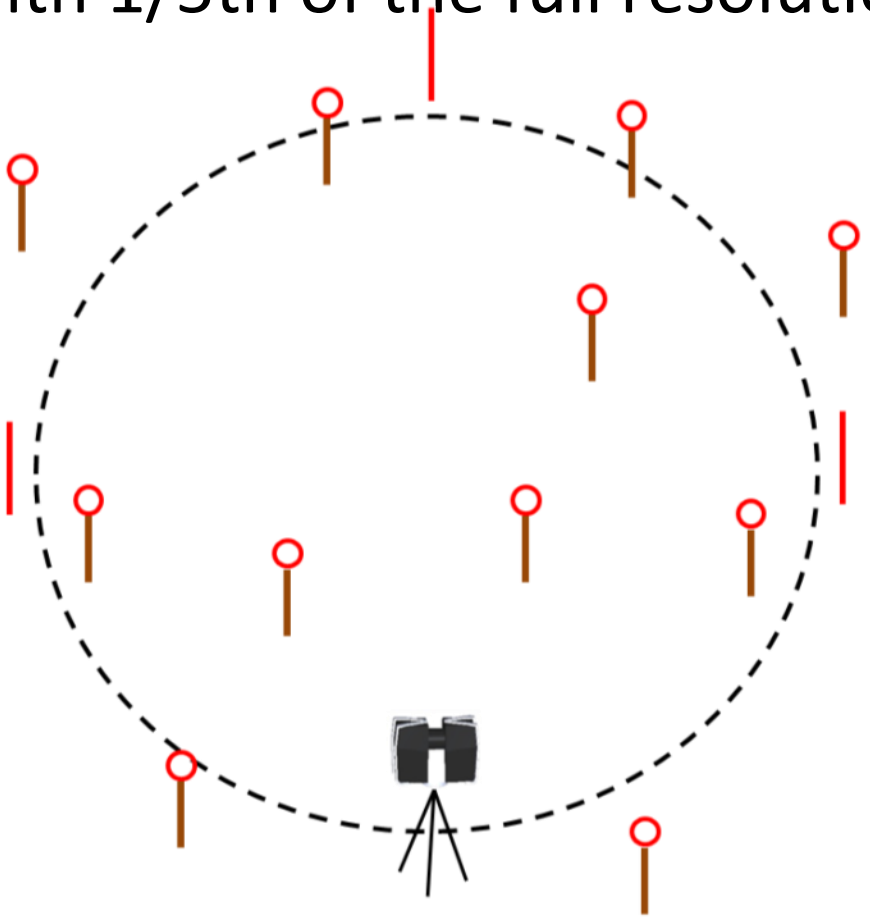

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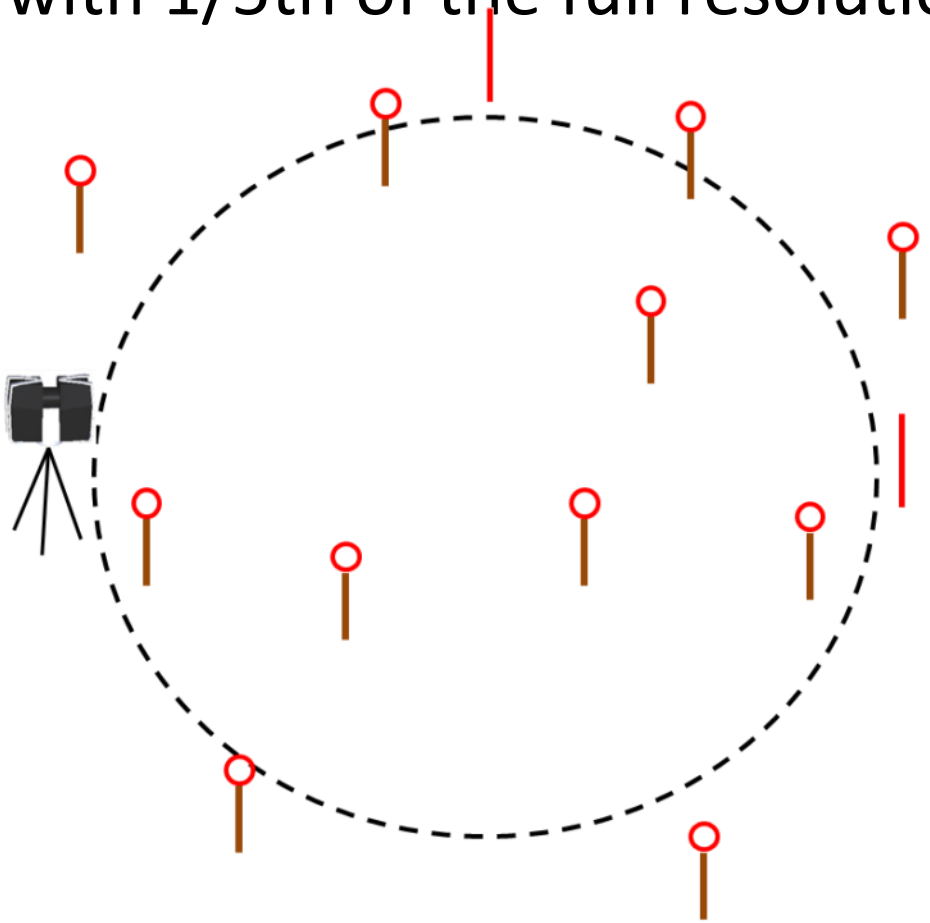

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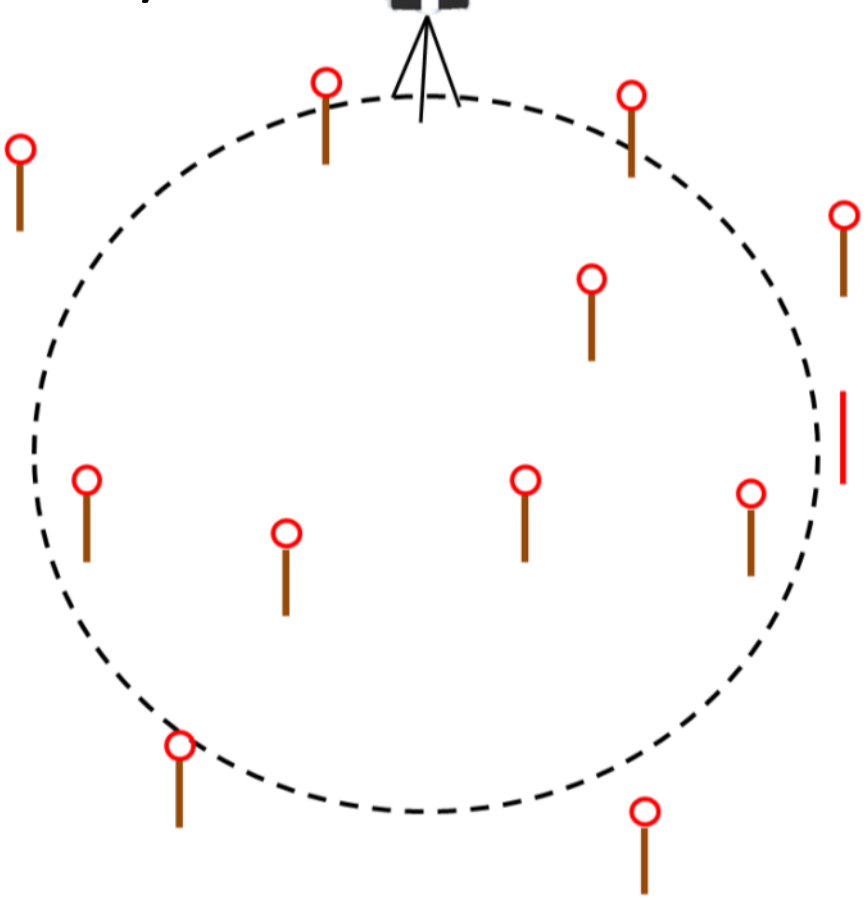

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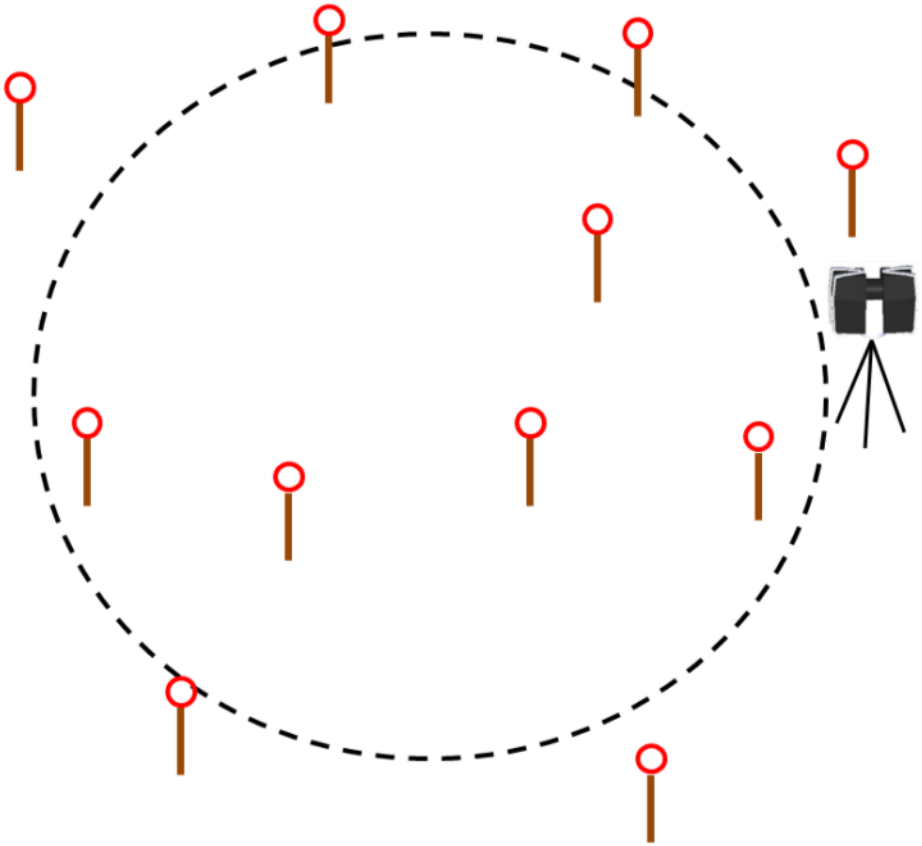
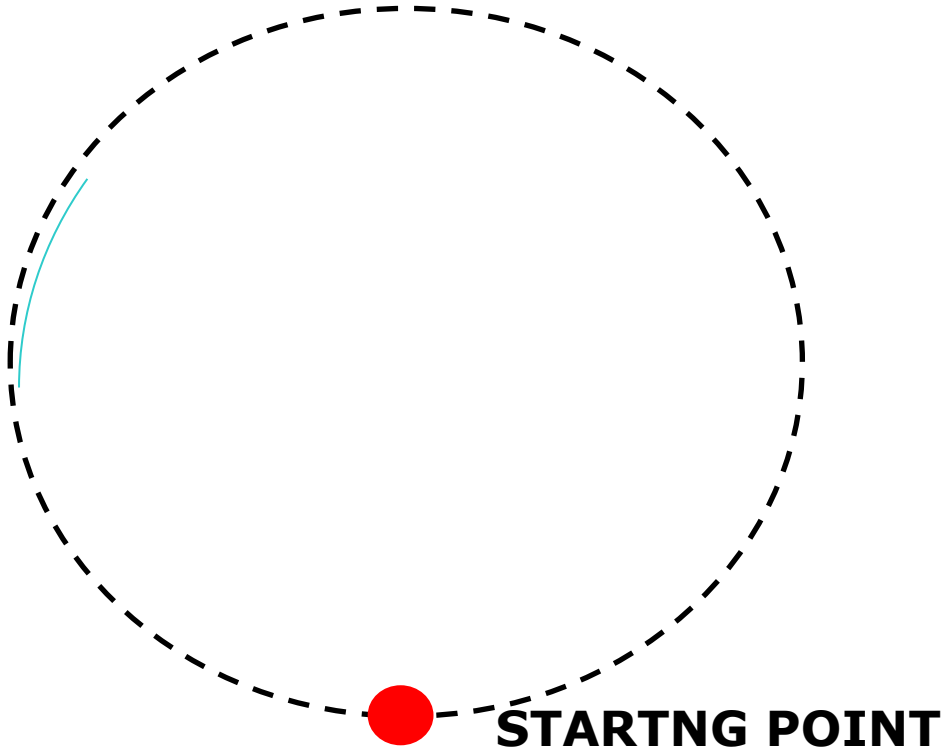


Methods
Field data acqusition

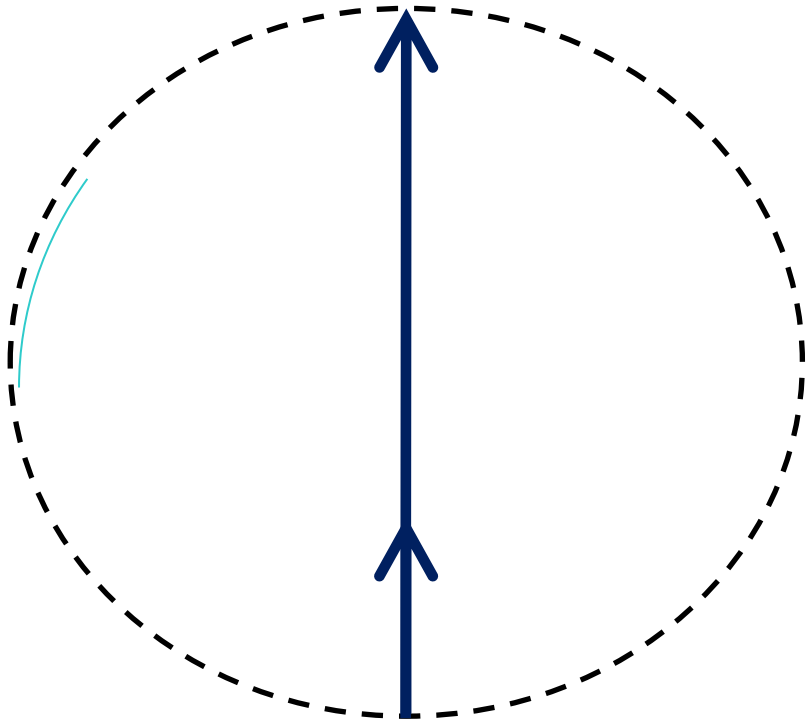
ZEB1 acquisition design:



Methods
Field data acqusition

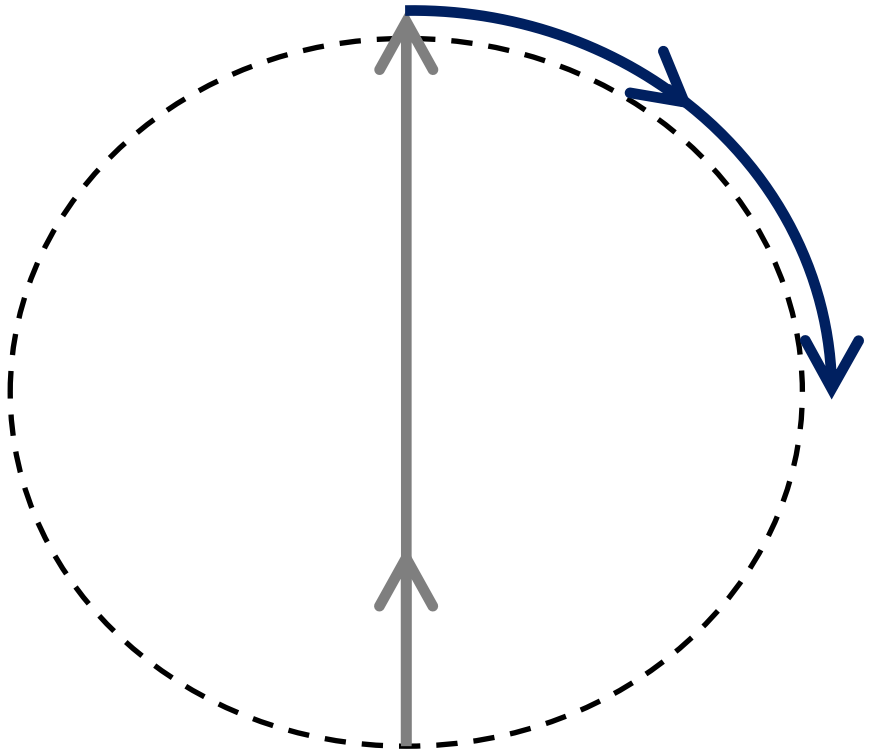
ZEB1 acquisition design:

- Walk in the plot



Methods
Field data acqusition

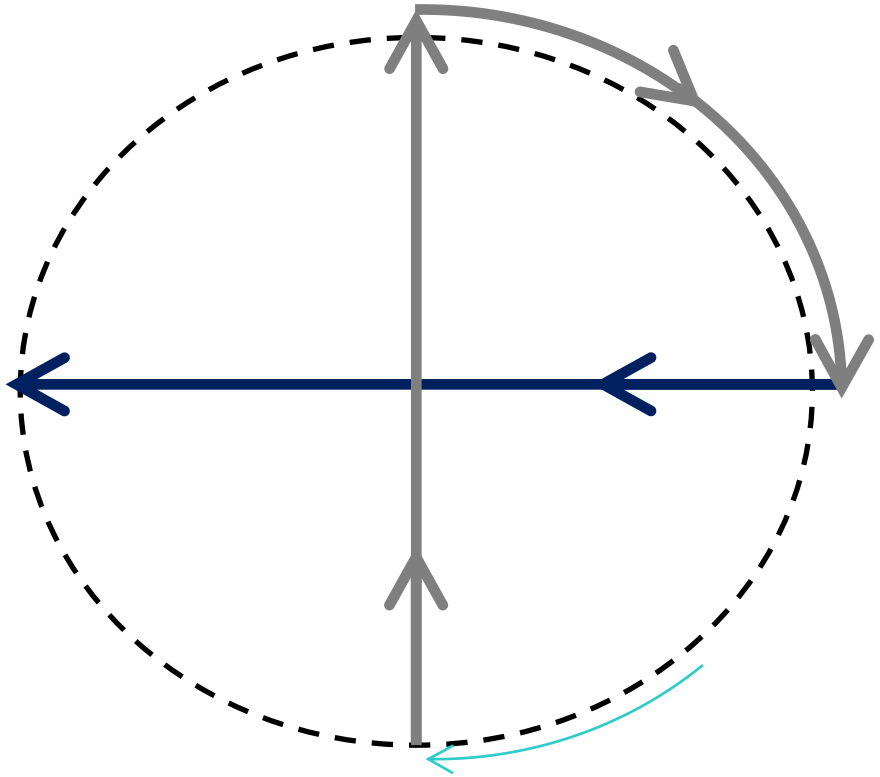
ZEB1 acquisition design:



Methods
Field data acqusition

ZEB1 acquisition design:

- **Making loop**



Methods
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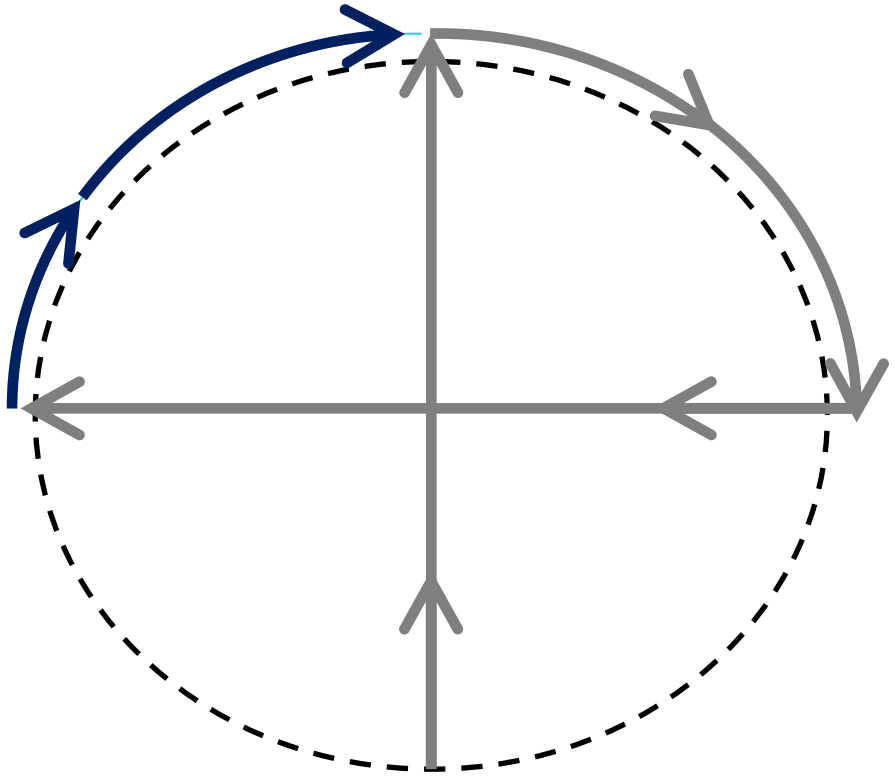

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Field data acqusition

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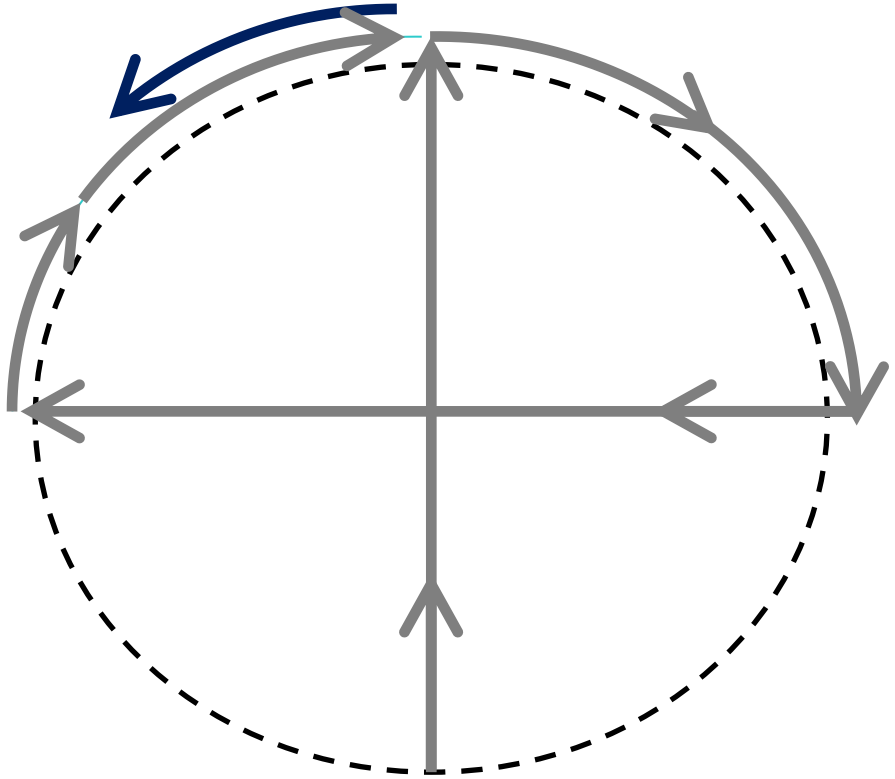
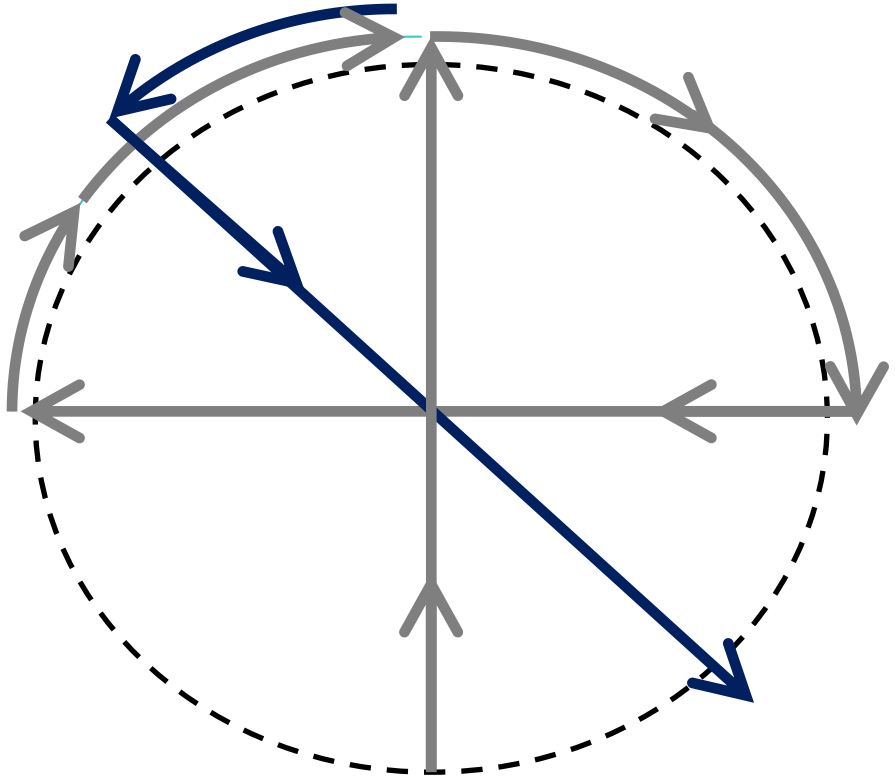


Methods
Field data acqusition

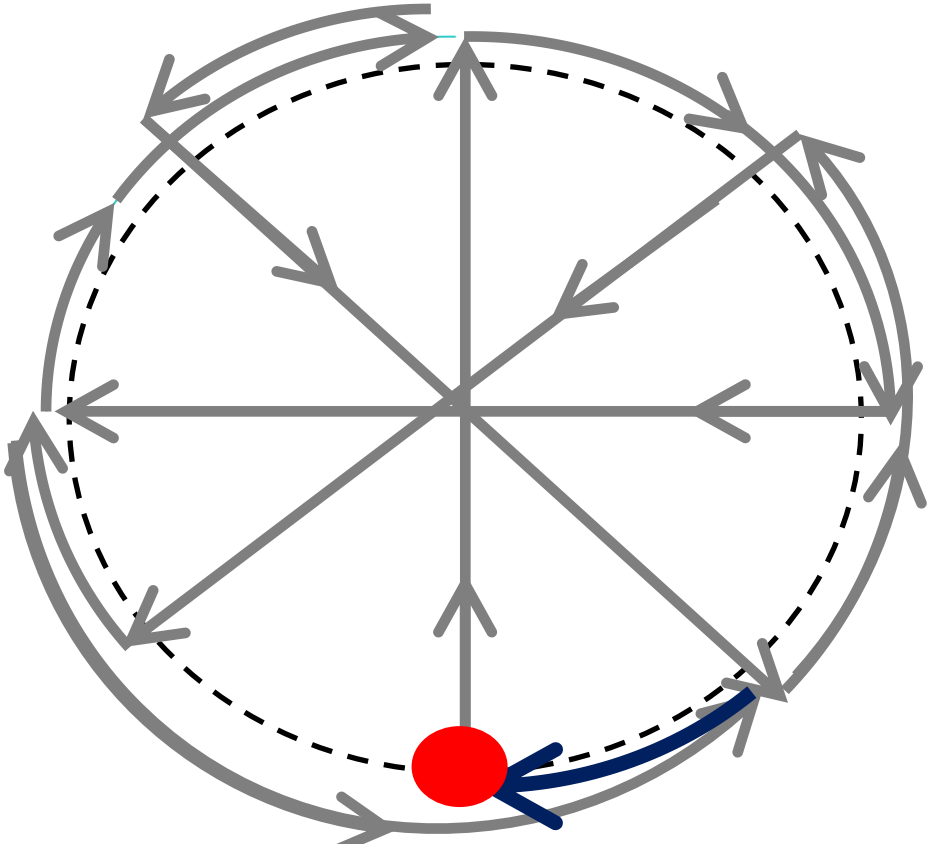
ZEB1 acquisition design:



Methods
Field data acqusition

ZEB1 acquisition design:

- **Closing the path**



Methods
Pre-processing

FARO

- Registering the 5 scans together by **fitting the spheres** with **SCENE**
- Export of the point cloud in .xyb

ZEB

- **Uploading** the scan in a **server** to refine the registering of the point cloud (average cost of **87 crédits/plot**)
- Download the registered scans in .laz

Methods
Processing the point cloud

Processing with **COMPUTREE**

- Algorithms from ONF-ENSAM (Othmani et al., 2011)

- Extraction of rasters of 50 cm of resolution:
  - **Density** of the points classified as **soil**
  - Digital Terrain Model (**DTM**)
  - Canopy Height Model (**CHM**)
- Fitting cylinders on stems & extraction of **DBH**

Analysis

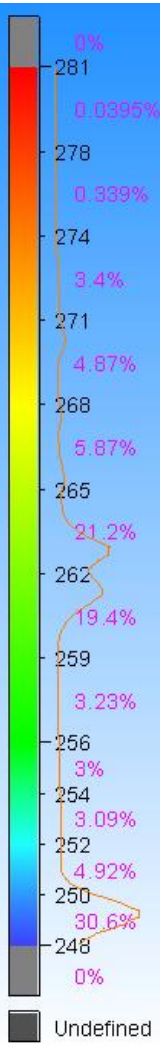
- Evaluation criteria for the estimated DBH

$$Bias = \frac{1}{n}\sum_{i=1}^{n}(y_i - y_{ri})$$

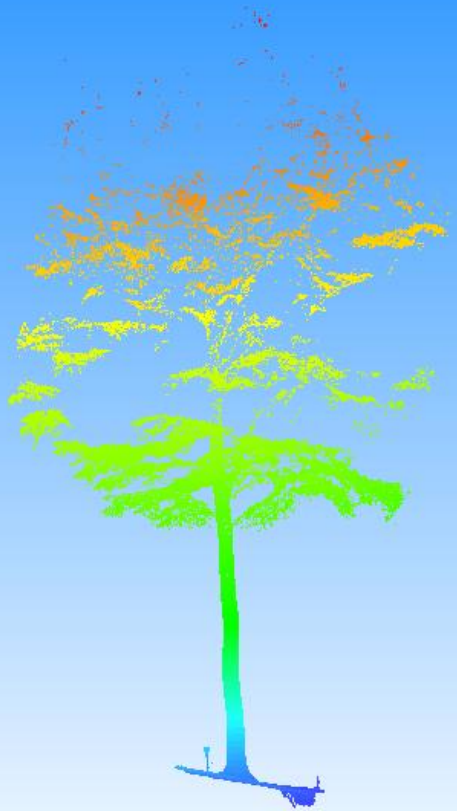
$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - y_{ri})^2}{n}}$$

Yi= DBH measured with tape
Yri= DBH estimated from LiDAR scan

Results
Point cloud of one tree in the plot



FARO with 5 scans

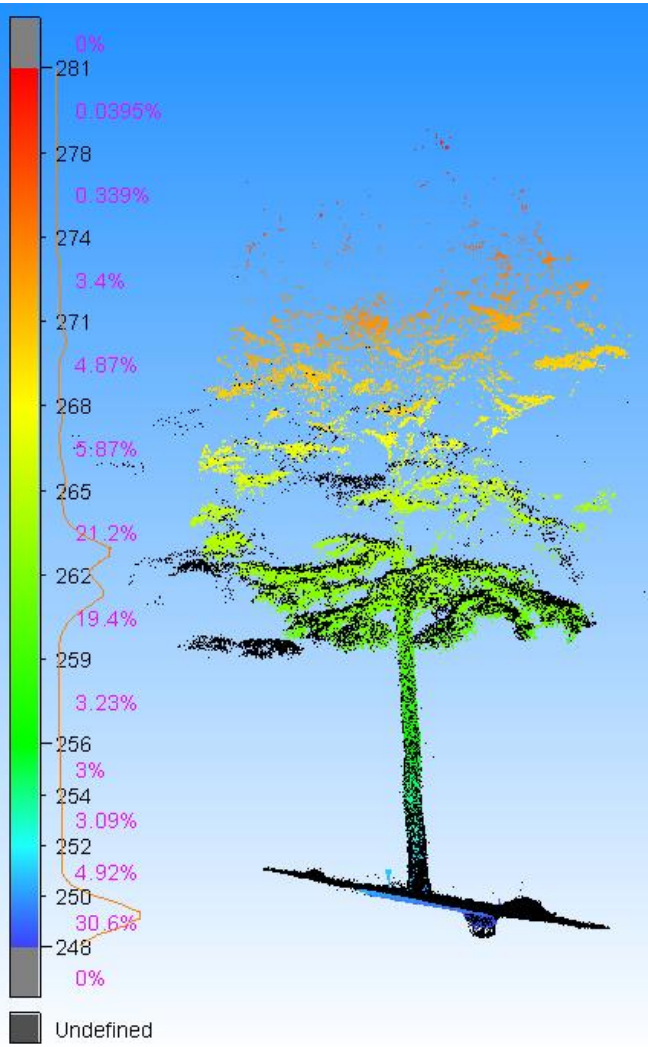


ZEB scan

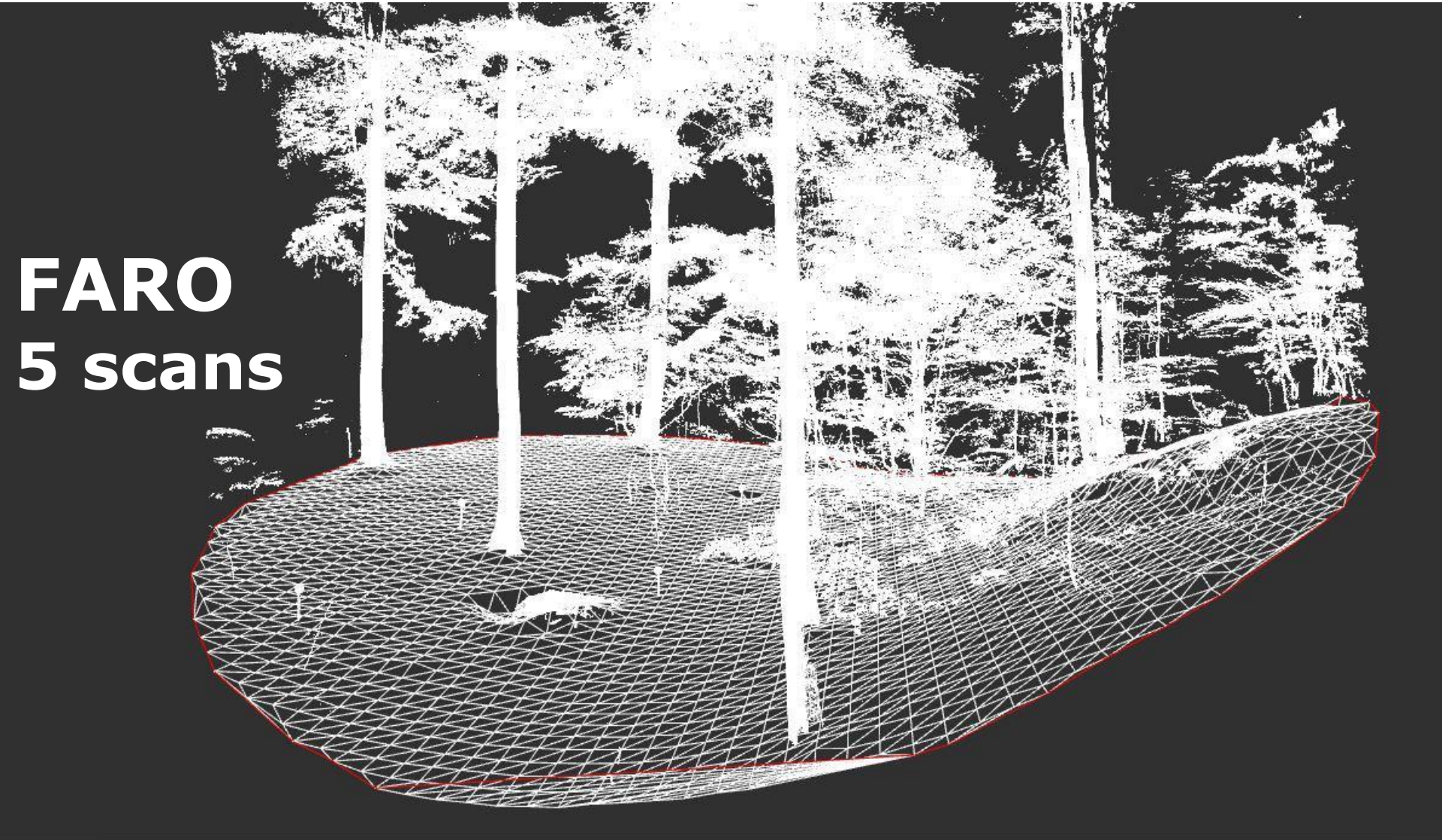
Beech from plot 10

Results

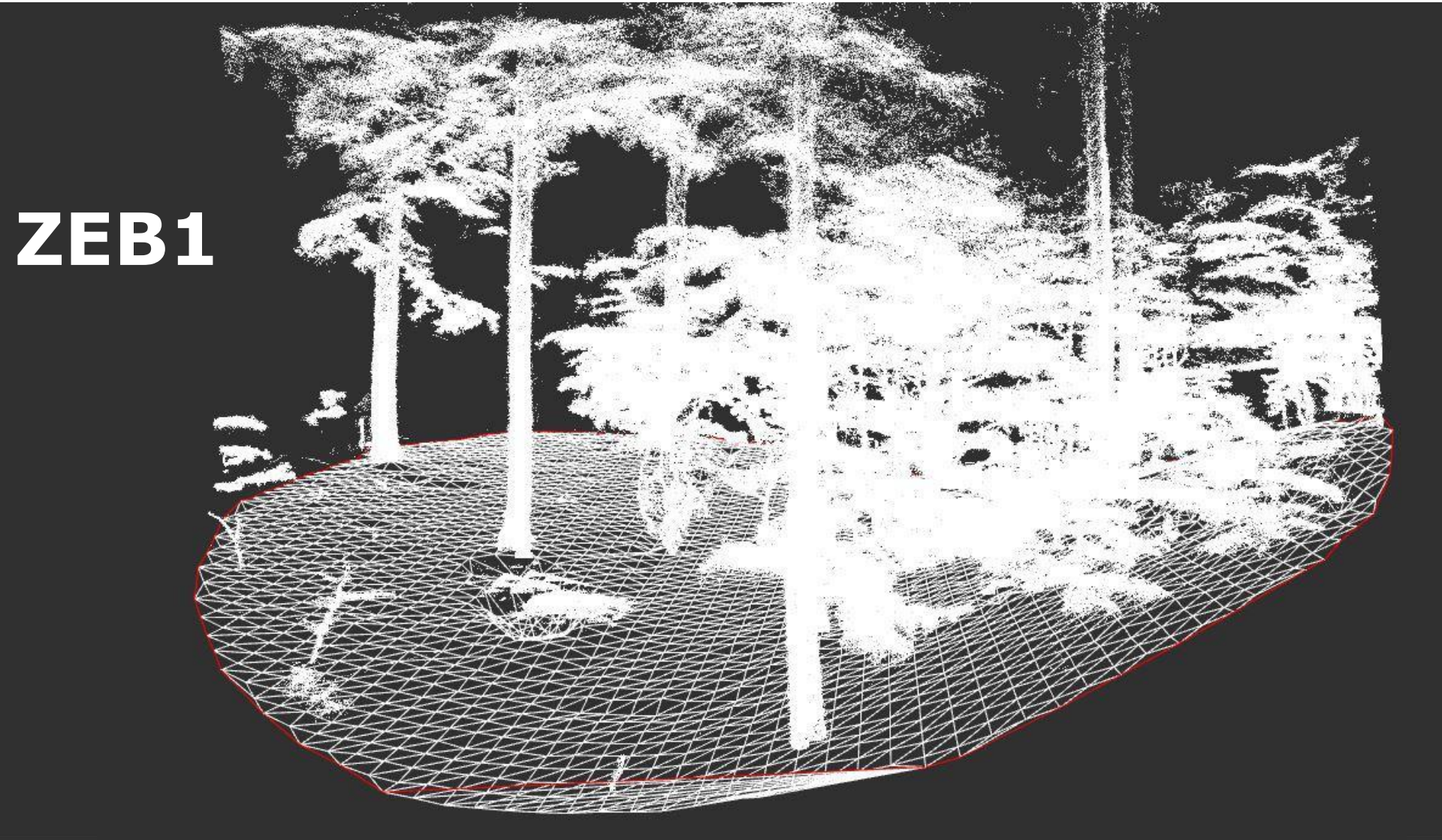
Point cloud of one tree in the plot



Results
Terrain extraction

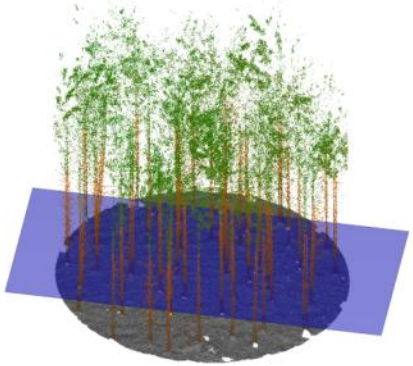


Results
Terrain extraction

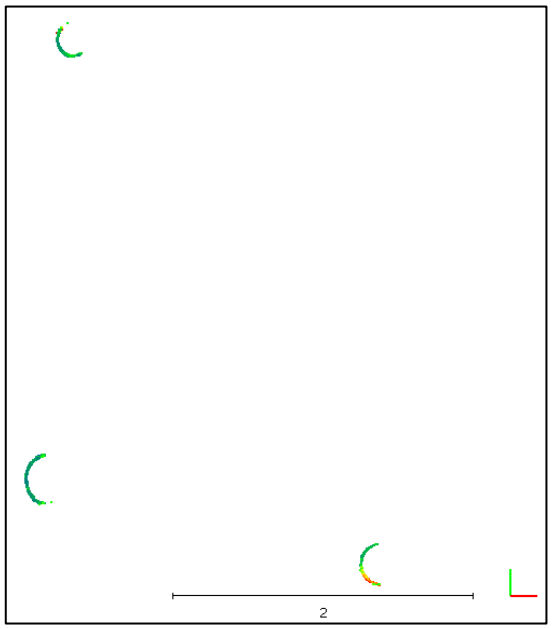


Results
« Consitency » of the point cloud

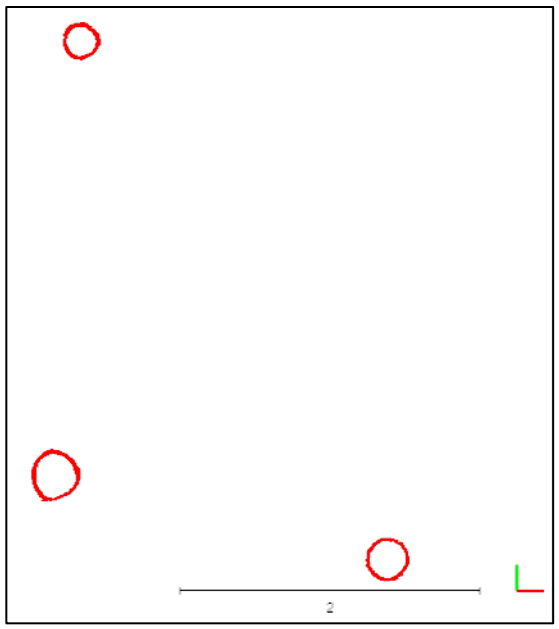
- Slice at 1.3m height
- Top view (from z)



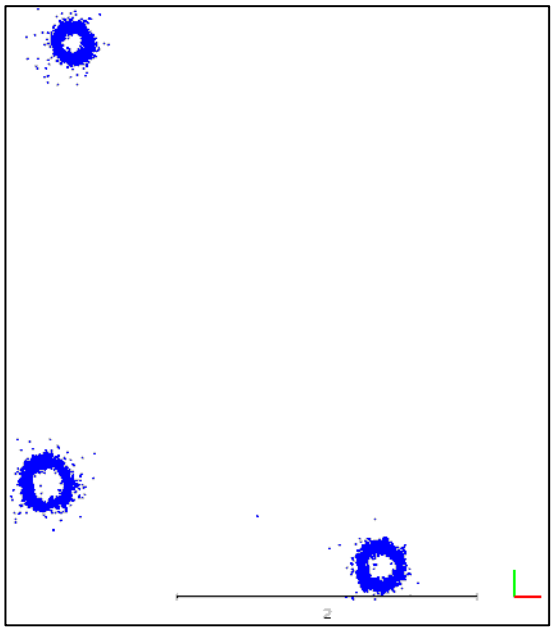
1 FARO scan



5 FARO scans

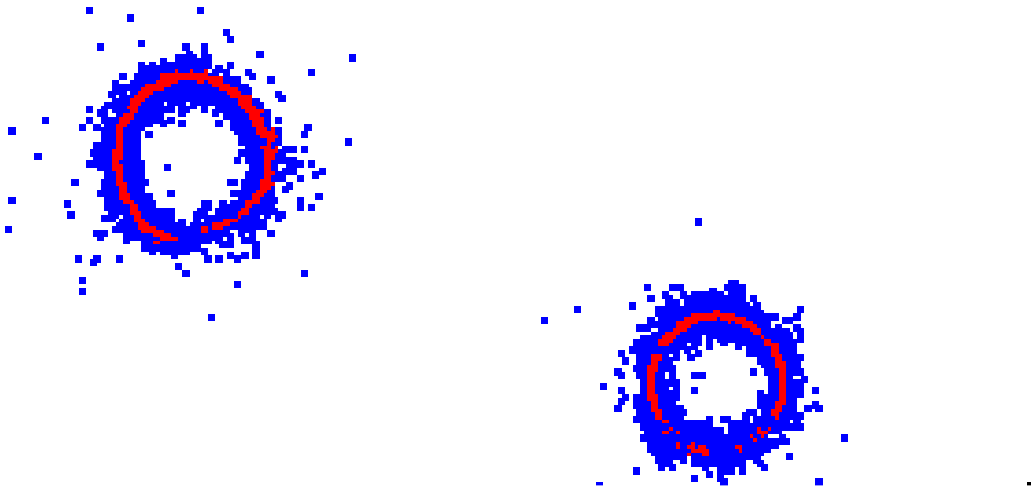


ZEB1 scan

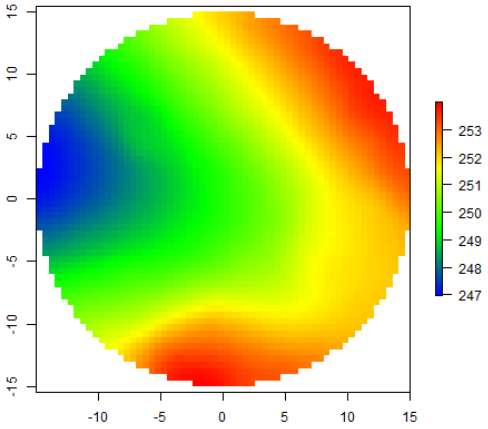
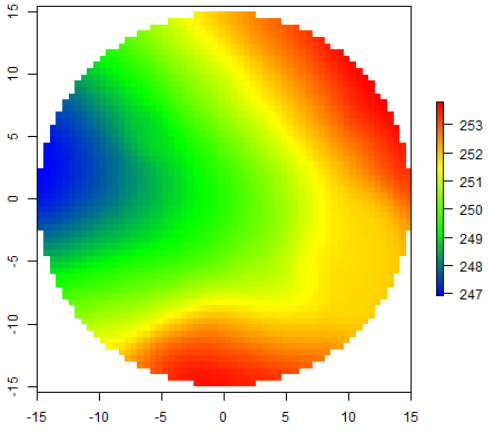
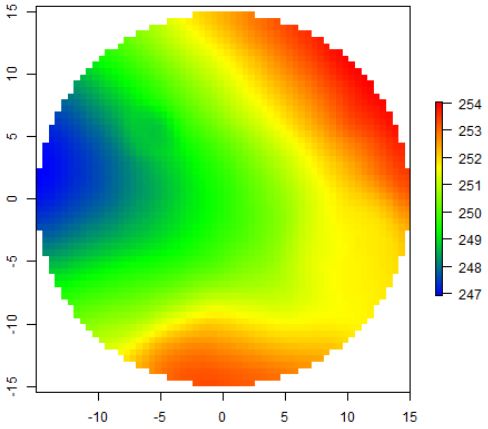
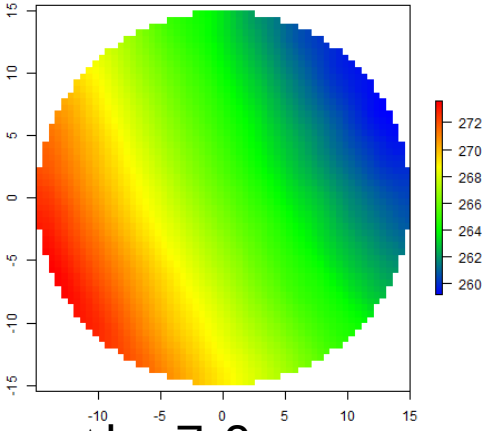
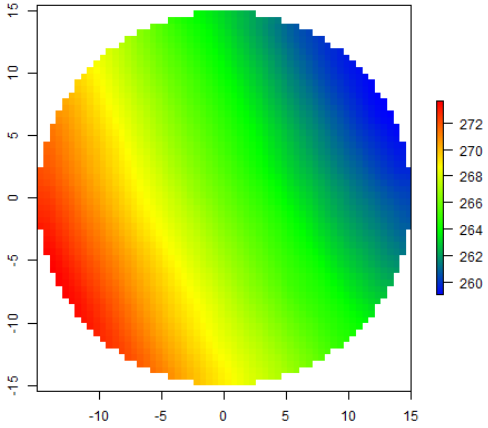
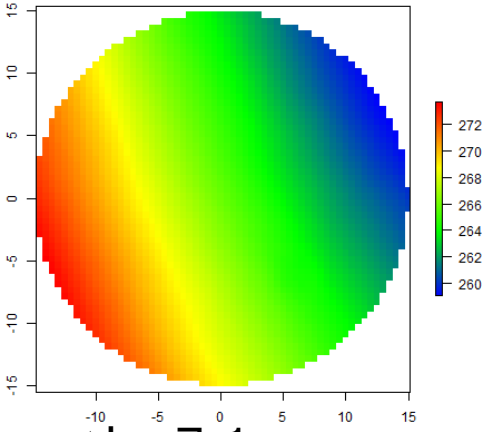


Results
« Consitency » of the point cloud

- 5 FARO scans VS ZEB scan

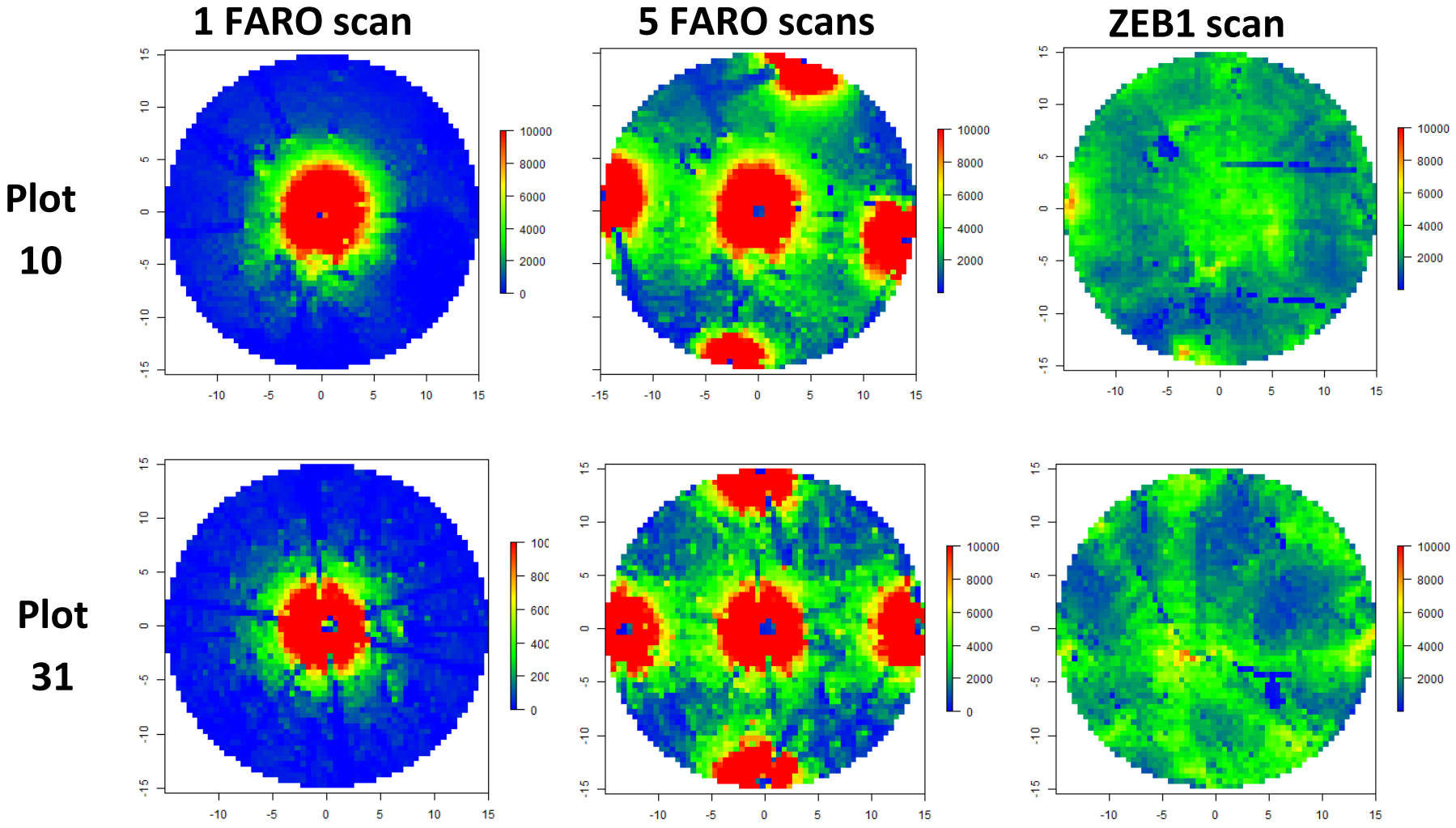


Results
Digital Terrain Model

	1 FARO scan	5 FARO scans	ZEB1 scan
Plot 10			
	Δh=14.4 m	Δh=14.5 m	Δh= 14.6 m
Plot 31			
	Δh=7.0 m	Δh=6.9 m	Δh=7.1 m

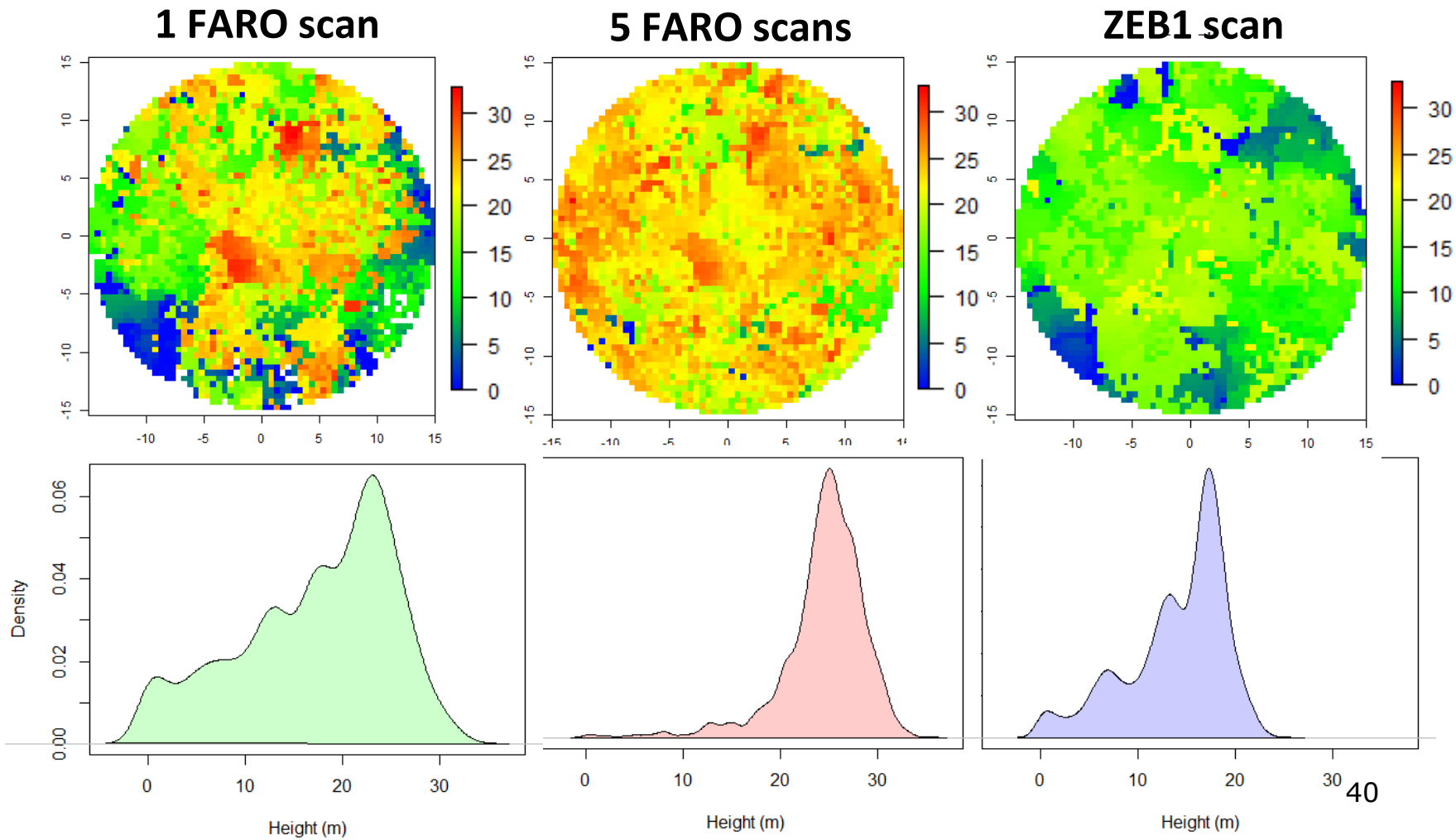
Results

Spatial distributions of points on the soil



Results
Canopy Height Model

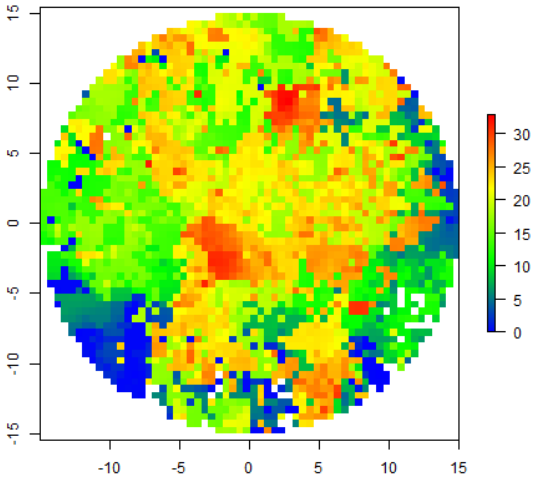
PLOT 10



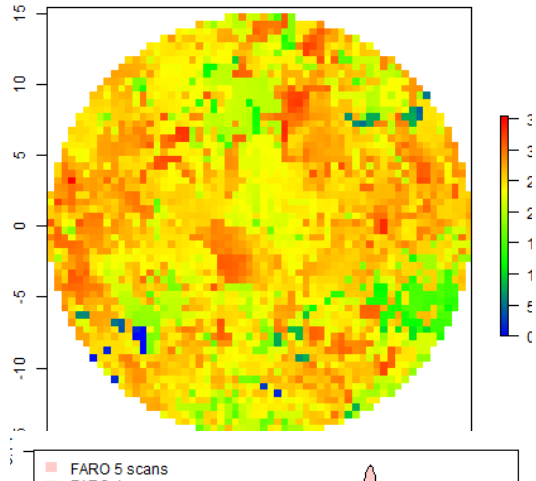
Results
Canopy Height Model

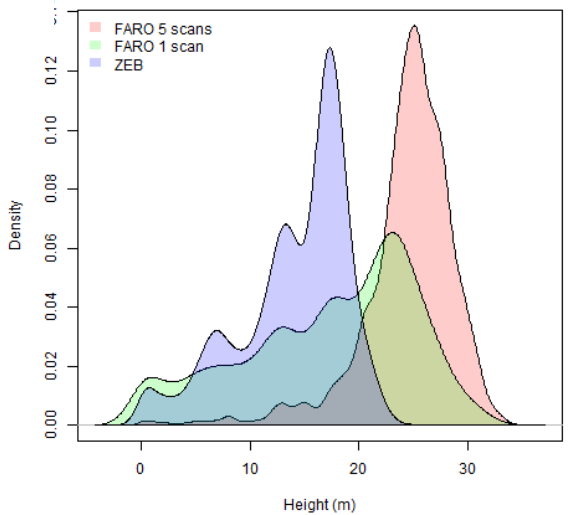
PLOT 10

1 FARO scan

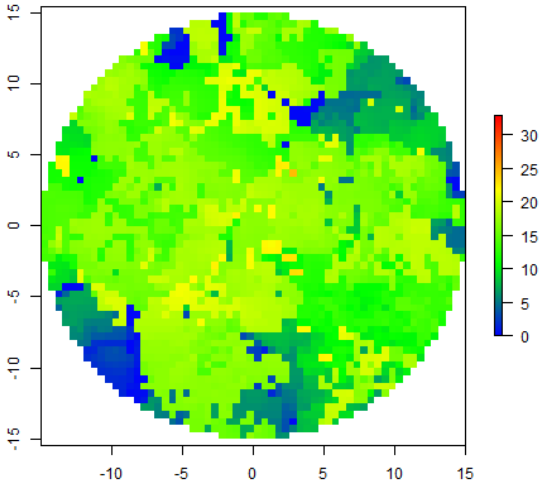


5 FARO scans

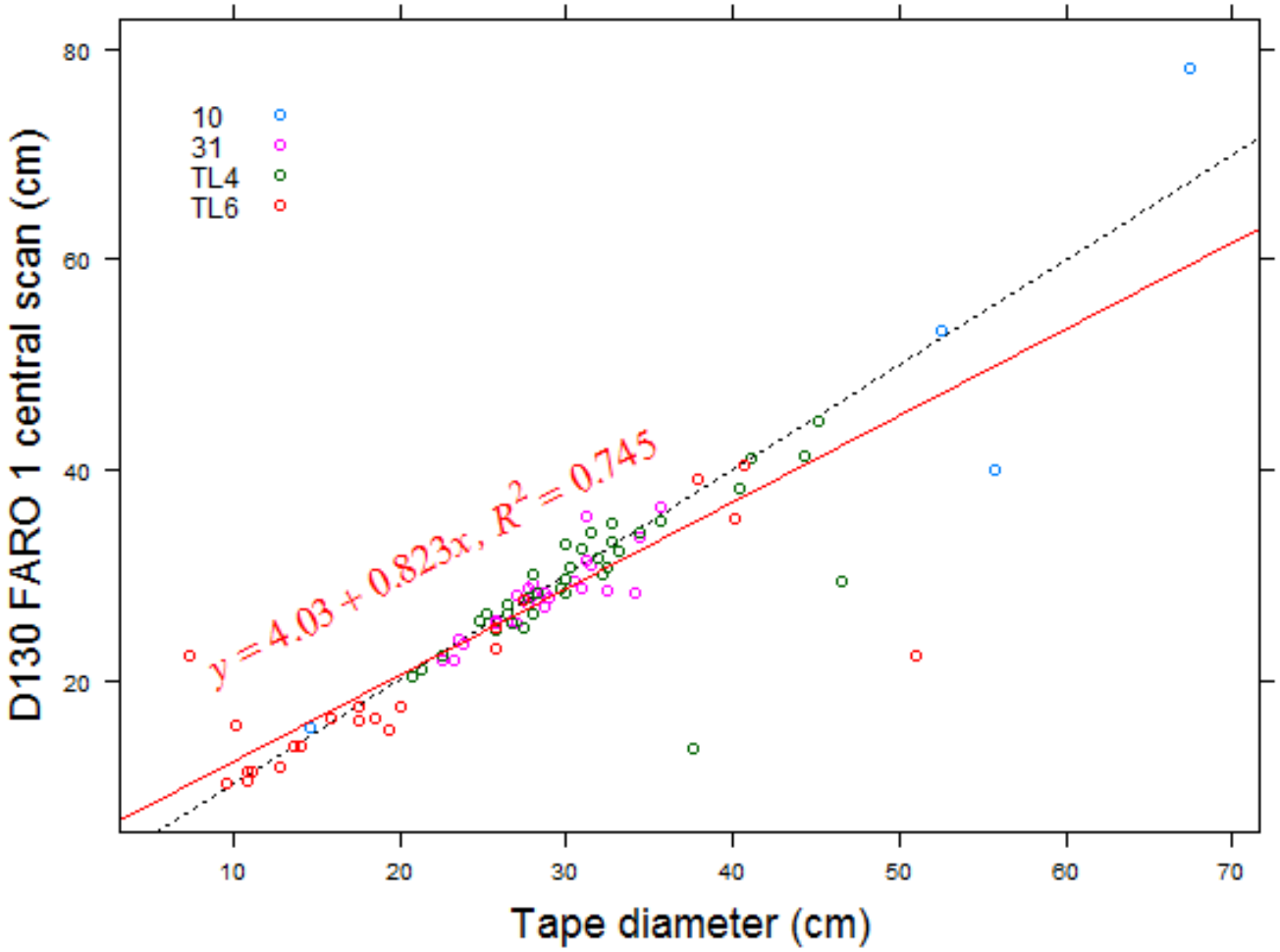




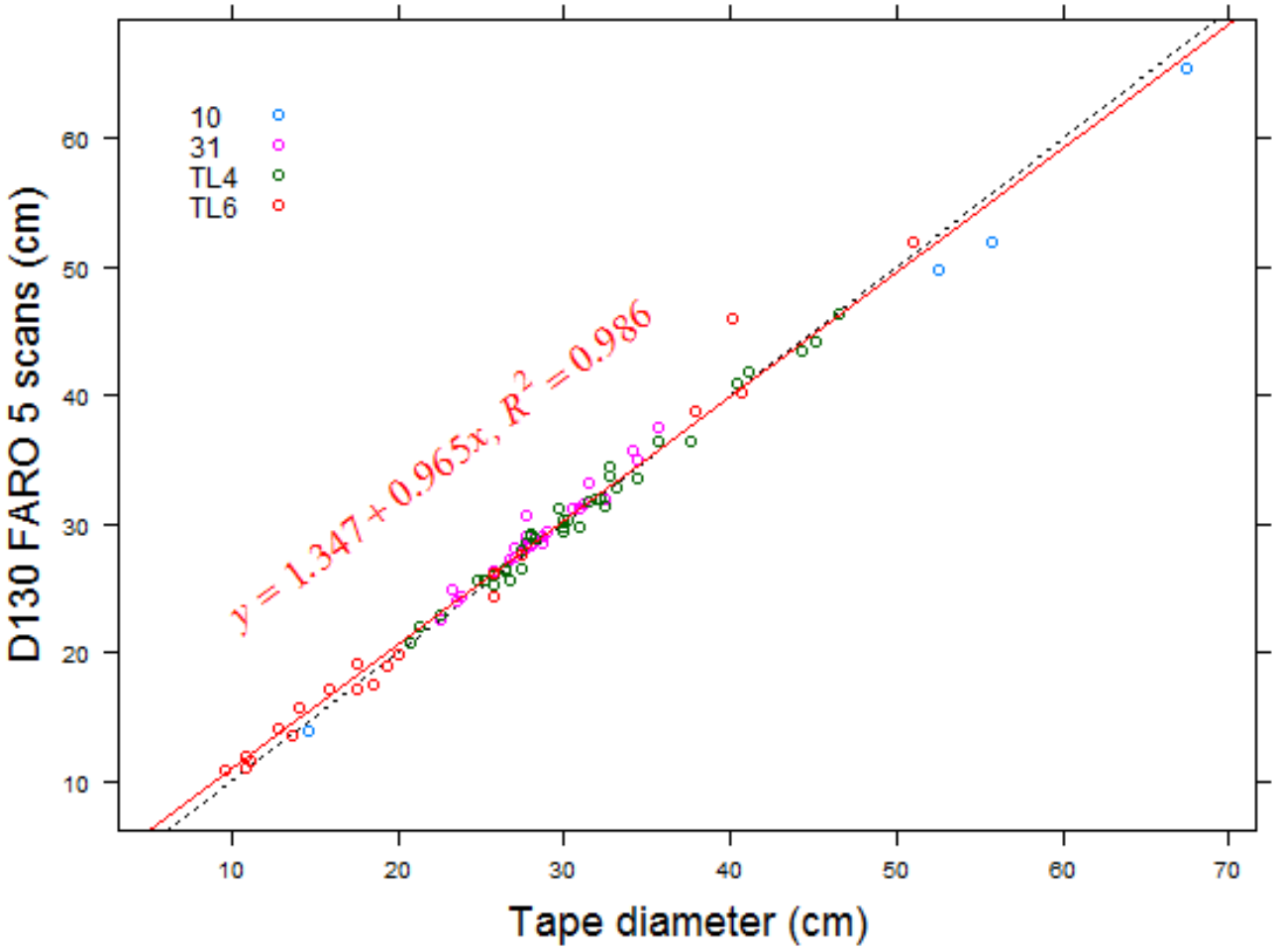
ZEB1 scan



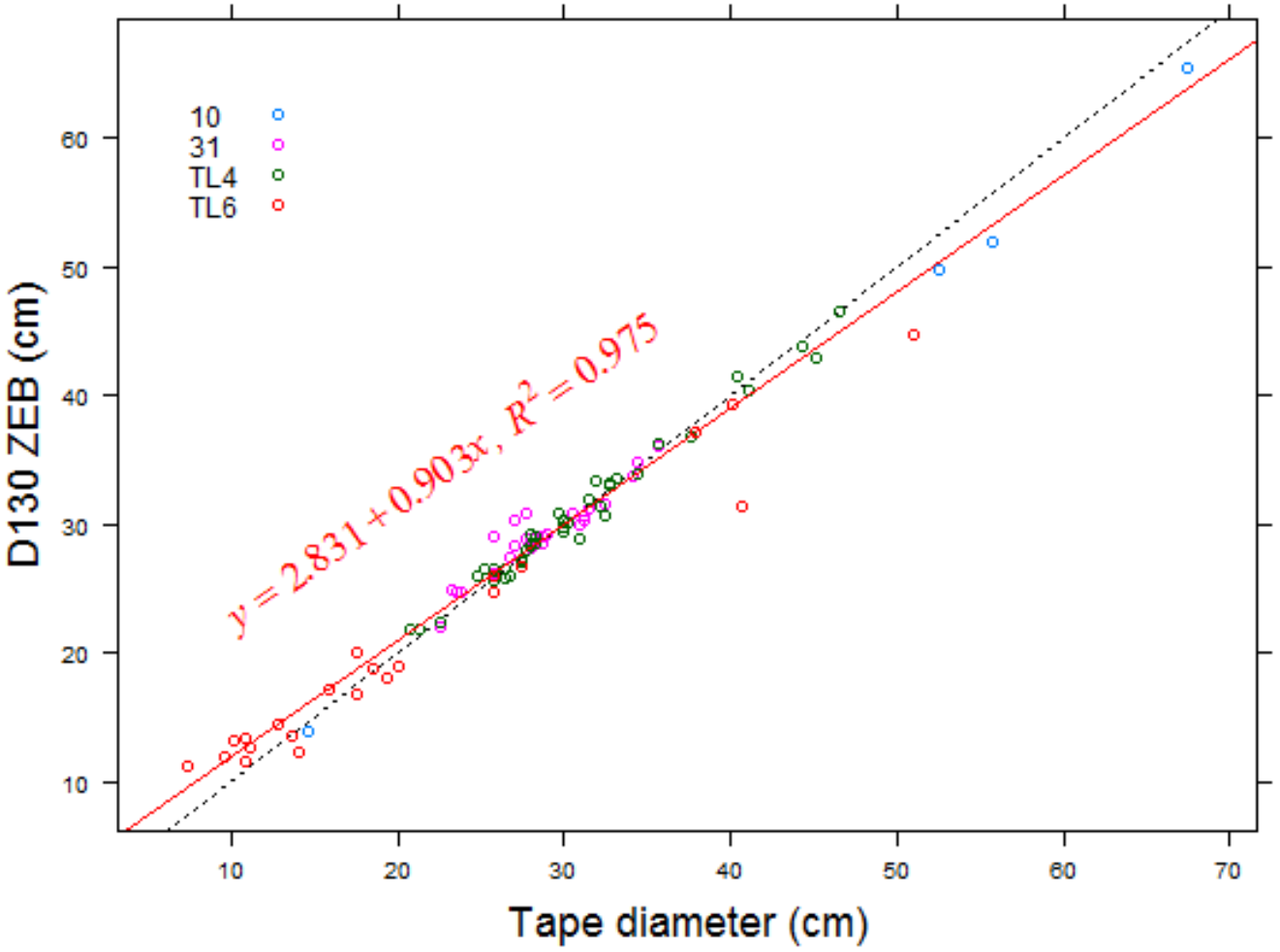
Results
DBH estimation: 1 FARO scan



Results
DBH estimation: 5 FARO scans

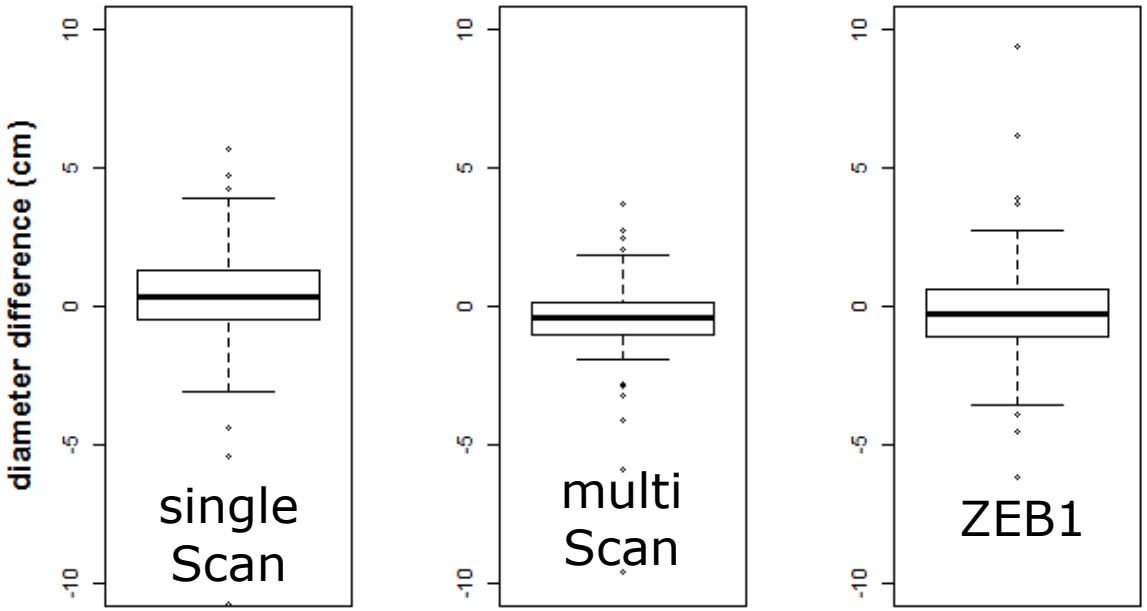


Results
DBH estimation: ZEB scan



Results
DBH estimation

Acquisition method	Bias (cm)	RMSE (cm)	RMSErel (%)	Detection (%)
Single FARO	1.0	5.3	18.6	75
Multi FARO	-0.5	1.6	5.8	89
ZEB1	-0.3	2.2	8.0	93



Time cost

	1 FARO scan	5 FARO scans	ZEB	Field measurements*
Field work				
Setting up	6 min	40 min	11 min	20-45 min
Scan(s)	4-6 min	35 min	13 min	
total	***10 min***	***1h15min***	***24 min***	***32 min***
Processing data**				
Plot pointcloud				
Registering	5 min	37 min	20 min	10 min
Computree	4 min	47 min	1h26	
total	***9 min***	***1h24***	***1h46***	***10 min***

** DBH measurement with tape + position of the trees (azimut, distance)*

** I7 3.4 Ghzx12 , 64 Go RAM, NVIDIAQUADRO K600

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Conclusion (1)

ZEB1

- Negative (-):
  - **Noisy** point cloud
    - Accuracy of 3cm
  - **Oversampling** of the **understory** within the range of the scanner
    - High beam divergence (∅12 cm @ 10m)
  - No reliable **CHM**
    - Range of the scanner
  - Upload the data on a **server**
    - offline check impossible

Conclusion (2)

ZEB1:

- Positive (+)
  - **Homogenous** distribution of the **points in XY**
  - Same **quality** of the **DTM** (vs 2 other methods)
  - **Good** quality of **DBH extraction**
  - High rate of **tree detection**
  - **Field work time** similar to the time needed with usual measurement tools

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Université de Liège

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Thanks

& thanks to Coralie Mengal, Cédric Geerts, Alain Monseur, Benoît Mackels & Fred Henrotay, the technical team

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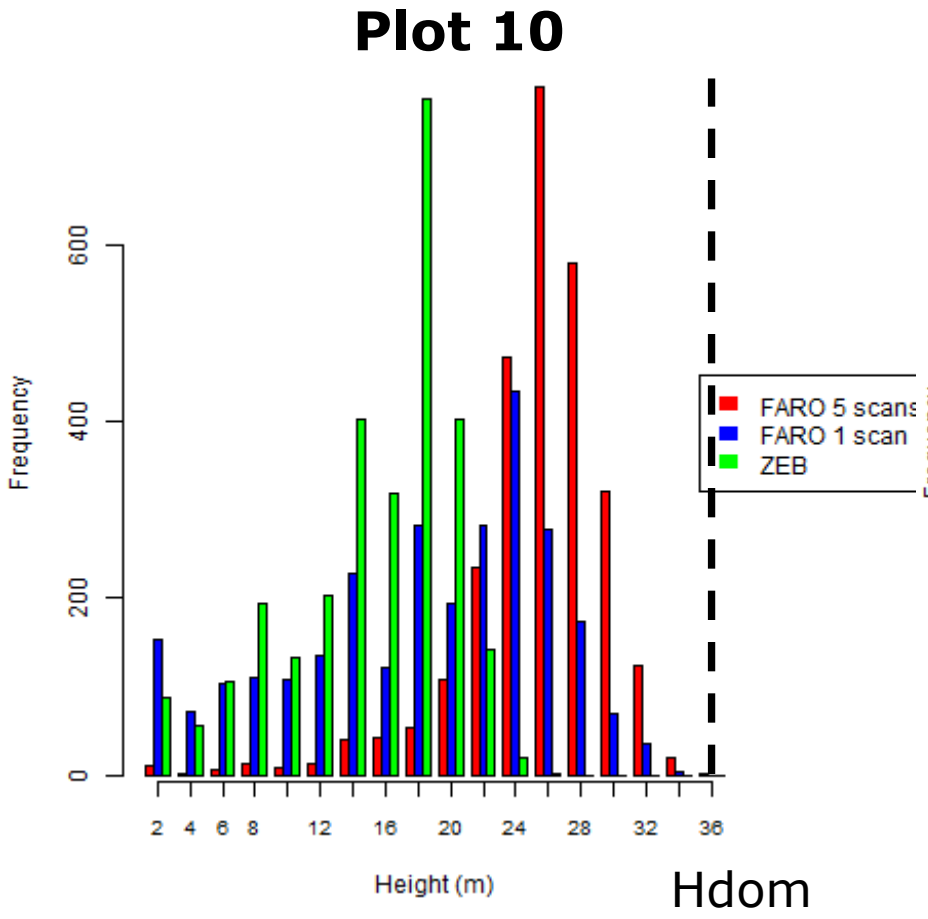
FFEM

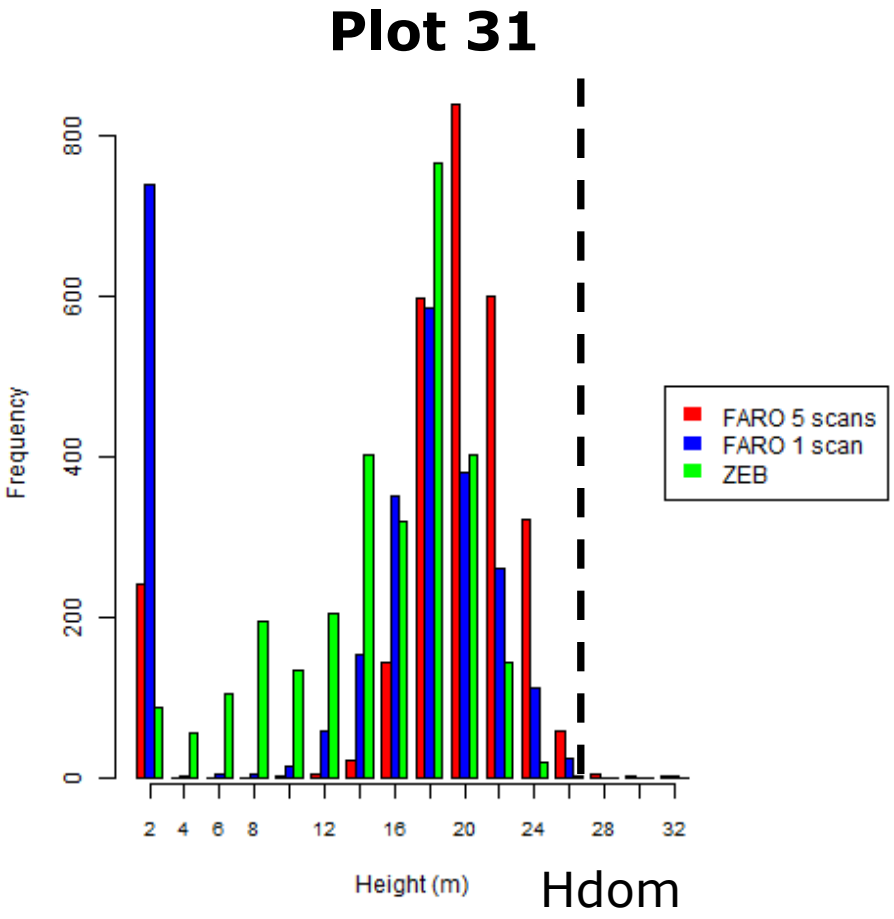
DYNAFFOR

Annexes

	FARO Fous 3D 120	ZEB1
Ranging method	Phase	Time-of-flight
Returns	Single	Single
Wavelength	905nm	905nm
Accuracy @ 10m	**2 mm**	**3 cm**
Max Zenith Range	305°	120°
Max Horizontal Range	360°	270°
Laser Class	3R	1
Range	**120 m**	**30 m**
Sample/sec	976 000	43 200
Beam divergence	0.19 mrad	~10-14 mrad
Colour/Image	Integated	No
Weight	**5 Kg**	**700 g**
Approx. Price	**~41 000 €**	**~22 000 €**
3 year Warranty & Maintenance	8 600 €	5 350 €

CHM


Plot 10
Frequency
0
200
400
600
2
4
6
8
12
16
20
24
28
32
36
Height (m)
Hdom
FARO 5 scans
FARO 1 scan
ZEB


Plot 31
Frequency
0
200
400
600
800
2
4
6
8
12
16
20
24
28
32
Height (m)
Hdom
FARO 5 scans
FARO 1 scan
ZEB

Discussion
DBH estimation

Acquisition method	Bias (cm)	RMSE (cm)	RMSErel (%)	Detection (%)
Single FARO	1.0	5.3	18.6	75
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ZEB1	-0.3	2.2	8.0	93

Maas et al., 2008	-0.67-1.58	1.80–3.25
Brolly and Kiraly, 2009	−1.6–0.5	3.4–7.0
Lindberg et al., 2012	0.16	3.8

Discussion
DBH estimation

Acquisition method	Bias (cm)	RMSE (cm)	RMSErel (%)	Detection (%)
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Liang et al. 2014	1.1	5.1	14.6	83

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