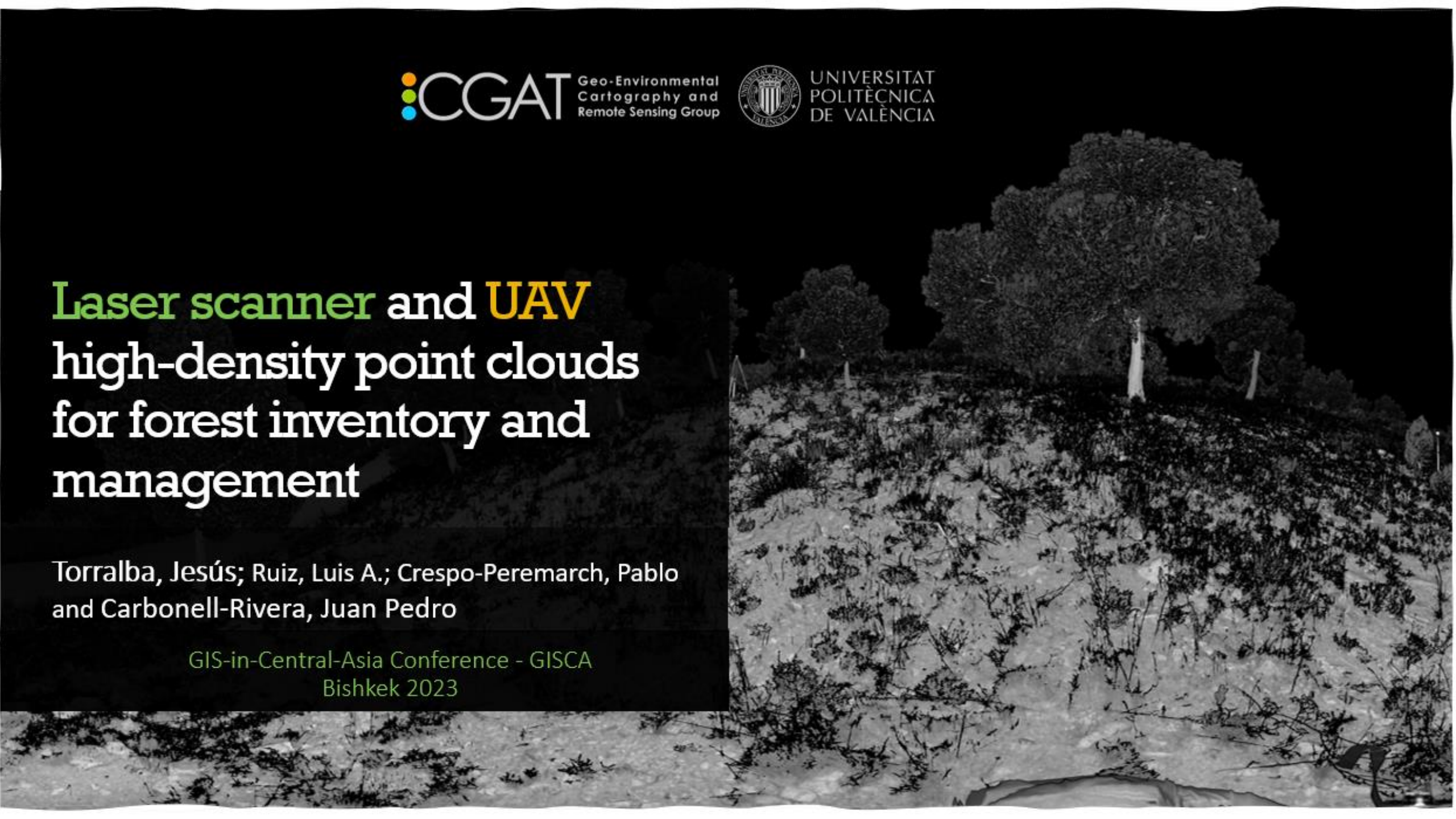


CGAT Geo-Environmental Cartography and Remote Sensing Group

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Laser scanner and UAV high-density point clouds for forest inventory and management

Torralba, Jesús; Ruiz, Luis A.; Crespo-Peremarch, Pablo and Carbonell-Rivera, Juan Pedro

GIS-in-Central-Asia Conference - GISCA
Bishkek 2023

Introduction

Dense point clouds in forest environments

Forest Management

✓Accurate collection of dendrometric information

✓ Improve confidence in forest managers' decisions.

✓ Support potential developments in forest management planning.

Forest parameters

✓Total aboveground biomass (BT)

✓Timber volume

These are modeled and predicted from other variables, such as diameter at breast height (DBH) and tree height (h).

✓Traditional inventory is a laborious process that can take years.

TLS and UAV

✓They allow the extraction of forest vegetation structure parameters.

✓ *TLS* captures the fine vertical structure of the forest, with problems in the upper part of the canopy.

✓*UAVs* generate point clouds of the canopy.

✓Complementarity

Point cloud methods

✓*h* maximum height returns analysis or statistical relationships inferred from return height distribution metrics.

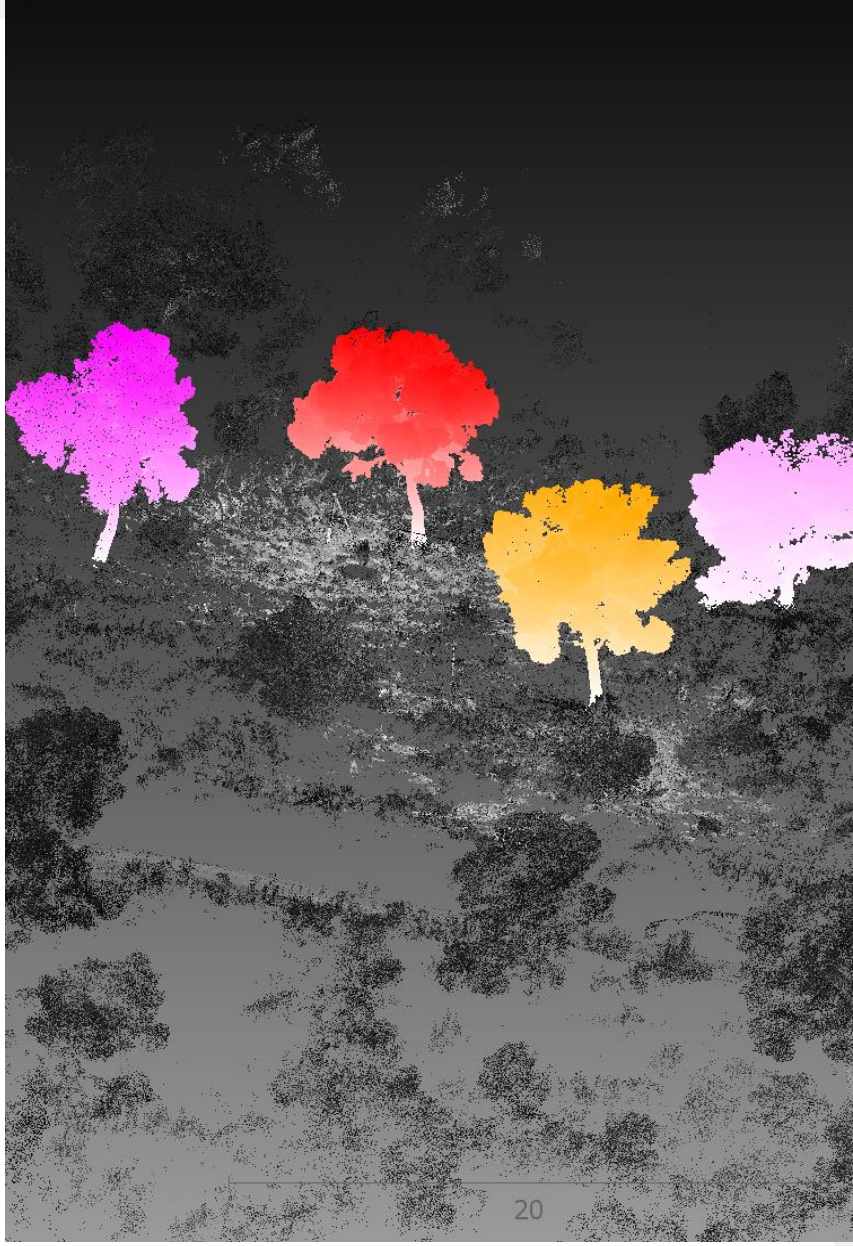
✓*DBH* algebraic or geometric mathematical models. For example, RANSAC (Schnabel et al., 2007).

Goal

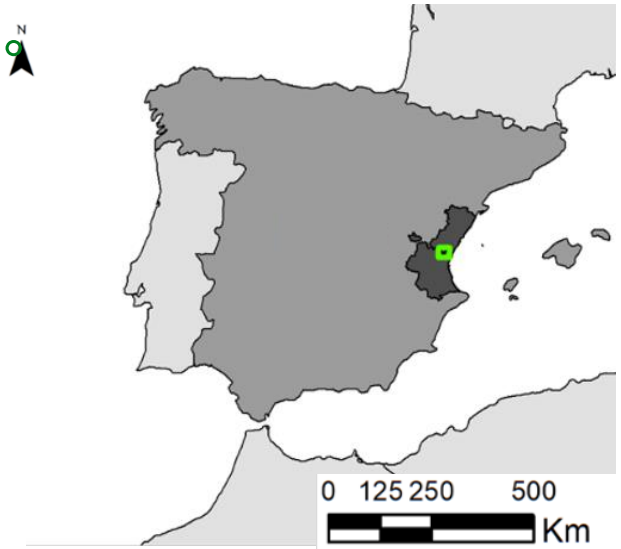
This study examined the use of TLS, UAV, and the fusion of both point clouds to estimate forest inventory parameters on individual trees.

We investigated the measurement of forest parameters in each dataset:

- (1) by multiple regression models based on point cloud height distribution metrics
- (2) by direct and automatic measurement.



Materials and Methods. Study area



- **Study area -** Located in the **Sierra Calderona Natural Park** between Valencia and Castellón, Spain.

- ***Pinus halepensis*** dispersed in an area of 260 x 35 m. Under silvicultural treatment for fire prevention.

	DBH (cm)	Height (m)	Capony base height (m)
Minimum	9.0	3.6	1.1
Maximum	49.6	15.2	3.6
Mean	29.5	7.9	2.4
σ	8.9	2.6	0.6

- Main **shrub species**:

Pistacia lentiscus L., Salvia rosmarinus, Juniperus oxycedrus L., Cistus albidus L. y *Rhamnus lycioides L.*

Materials and Methods. Data sets

Manual inventory

40 *Pinus halepensis*

Field

- Diameter at breast height (*dn*) > 5 cm | *Caliper*
- Dominant height (*h*) | *Vertex III HÄGLOF hypsometer*
- GPS position | *Leica GNSS 1200 (RTK)*

Office

Total aboveground biomass (*AGB*) *Montero et al. (2005)*

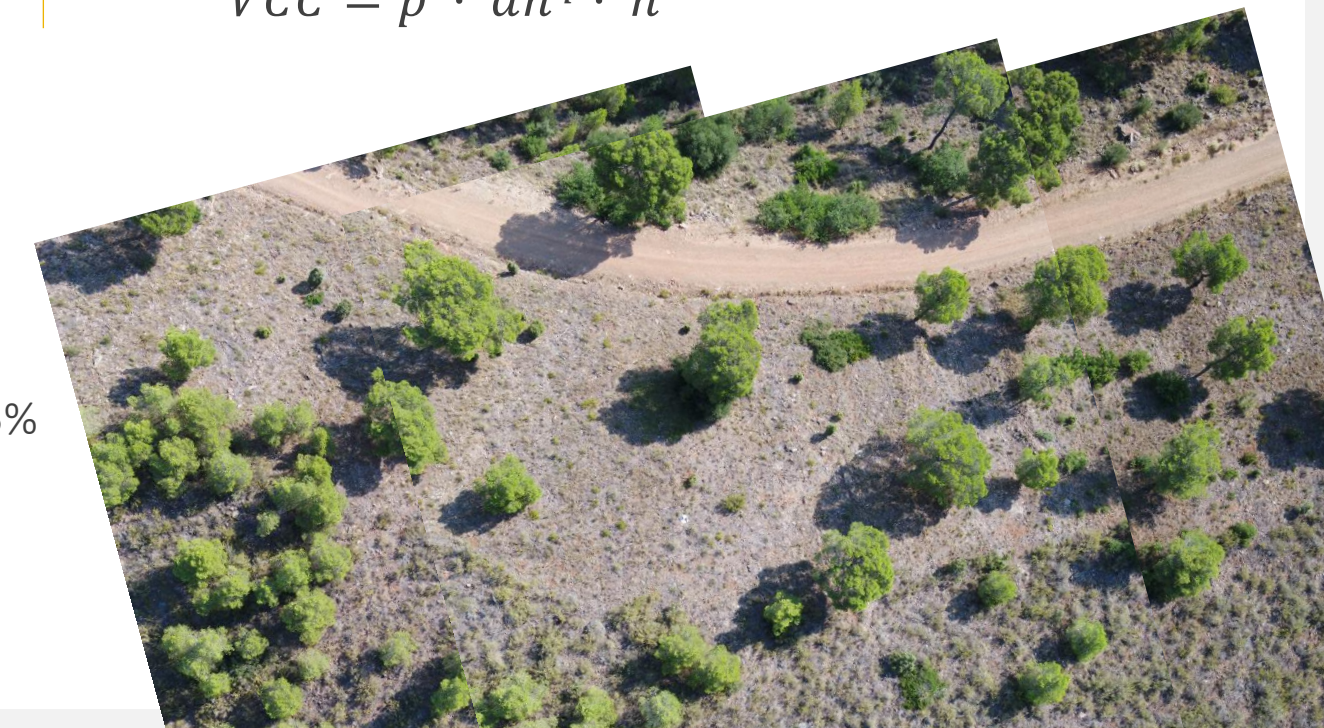
$$BT = CF \cdot e^{a} \cdot dn^{b} \qquad CF = e^{\frac{SEE^2}{2}}$$

Timber volume with bark (*VCC*) | *3IFN, Valencia (MAPA, 2007)*

$$VCC = p \cdot dn^{q} \cdot h^{r}$$

UAV

- *Platform* - UAV quadcopter DJI Inspire 2.
- *Sensor* - Camera RGB DJI ZENMUSE X5S.
- Duration of 7 min. Average altitude of 56 m. 75% overlap. Acquisition angle 65º. No wind.
- 144 imágenes with an extension of 1 ha. 6 Ground Control Points.



Materials and Methods. Data sets

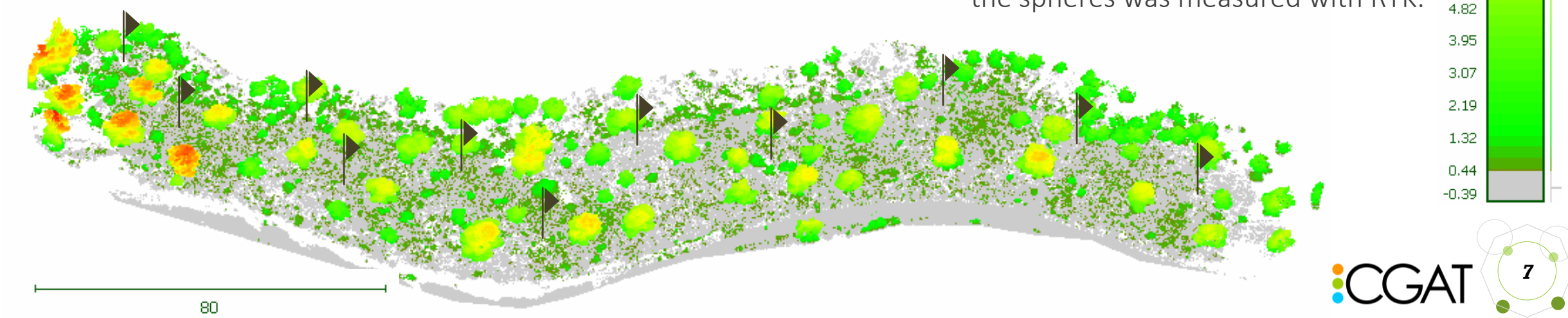
TLS

- Sensor characteristics

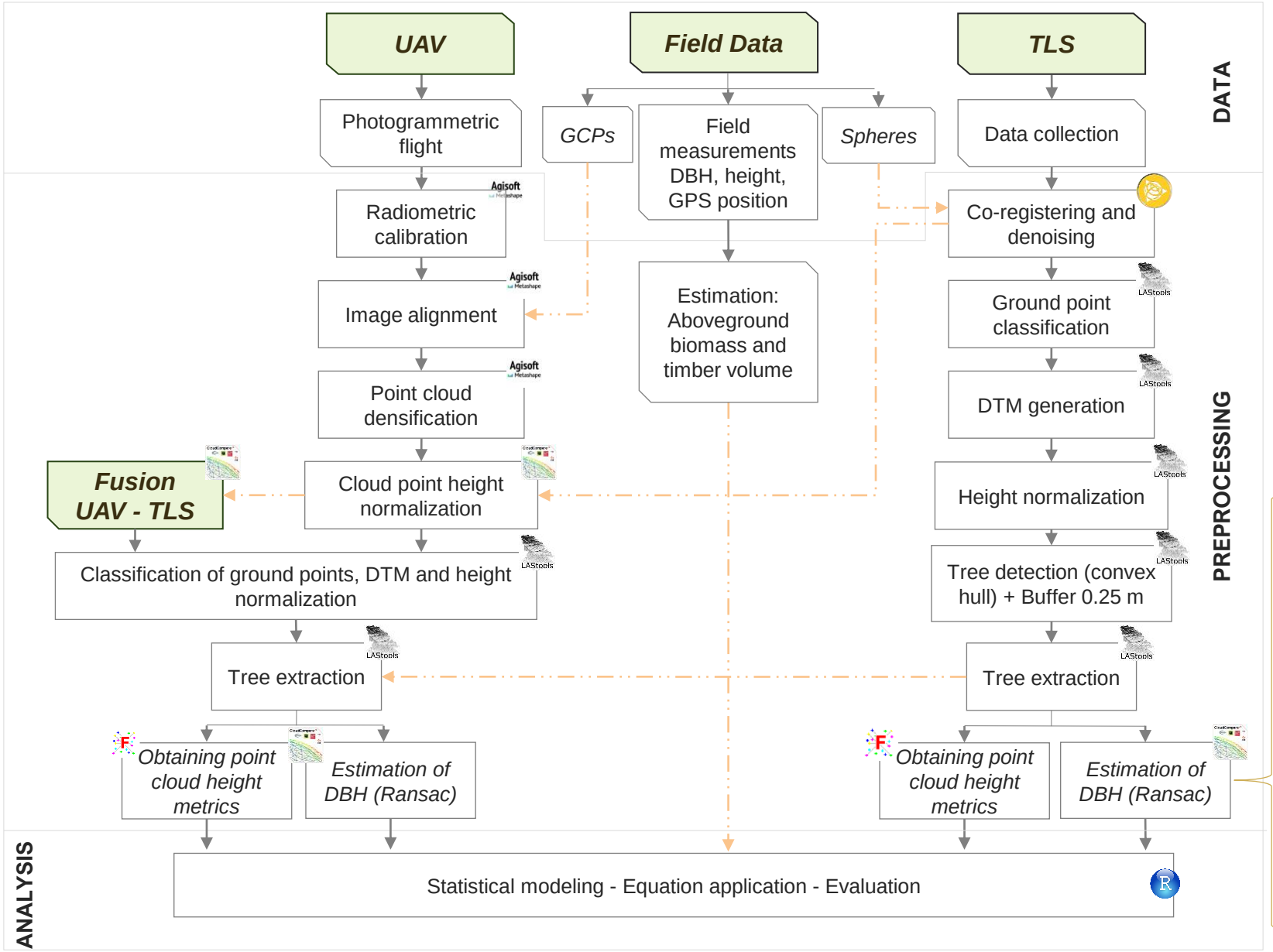
Sensor	Trimble TX6
Range	0,6 a 120 m
Accuracy	< 2 mm
Beam divergence	80 µrad
Scan angle	360ºx317º
Wavelength	1500 nm
Duration of scan	**5'**
Points density	≈ **1000 points/m²**

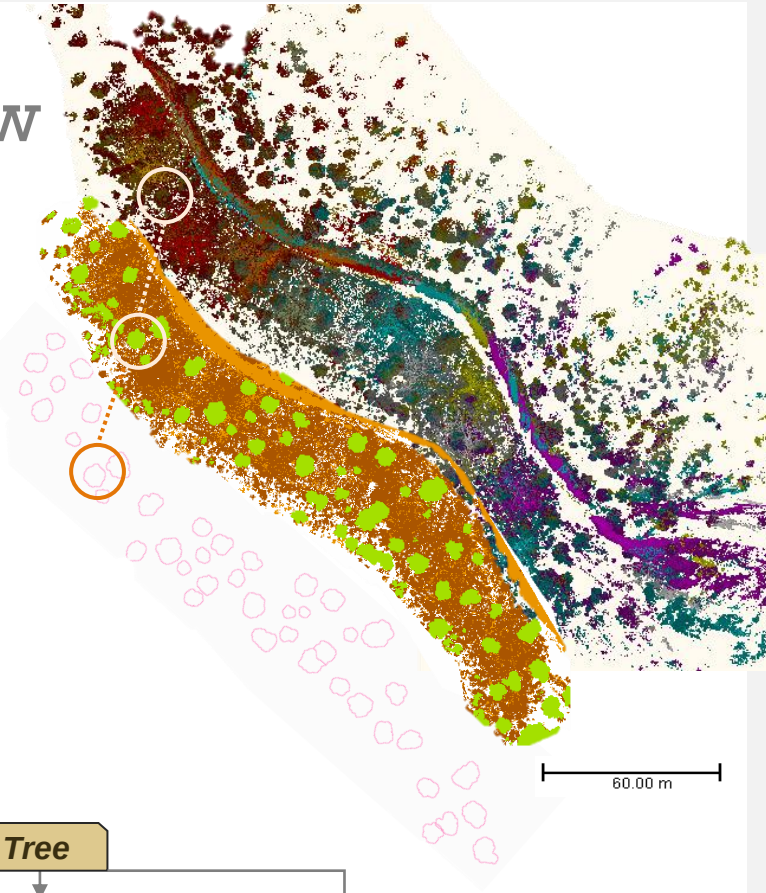
- TLS scanner positions

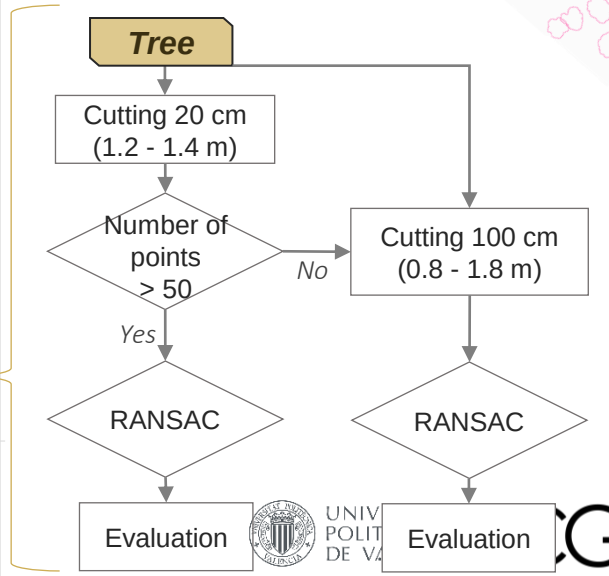
11 scanner positions ( ) in zigzag. 8 reference targets (4 targets visible from each position). The position of the spheres was measured with RTK.



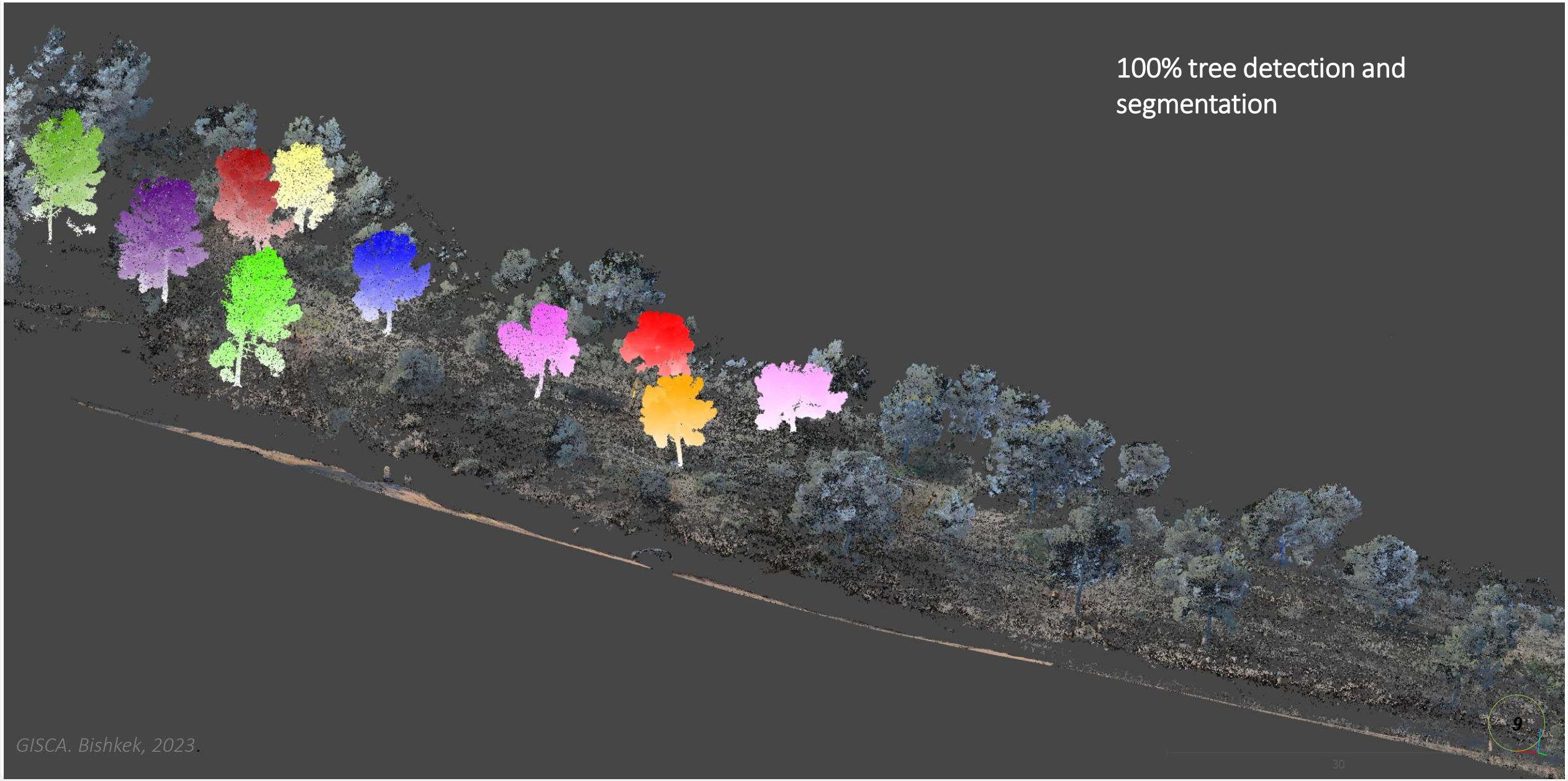
Materials and Methods. Methodology Overview



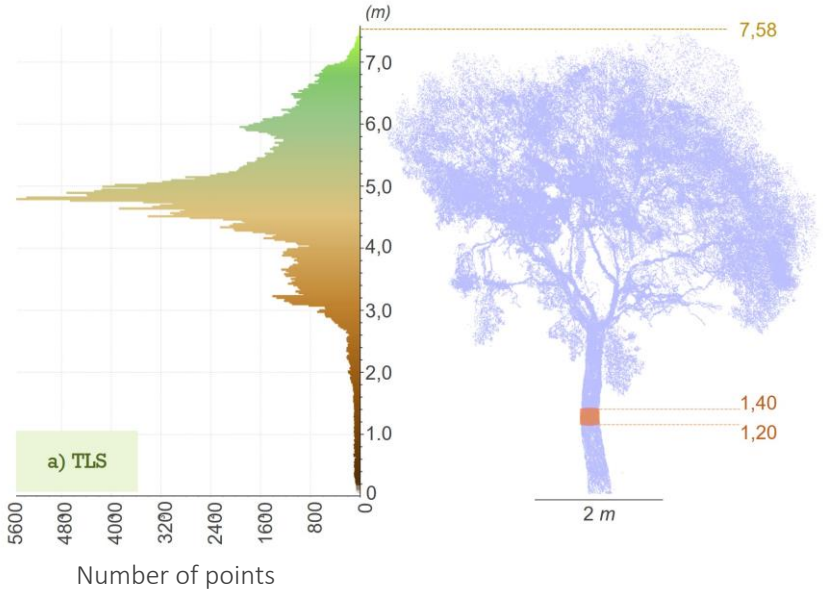


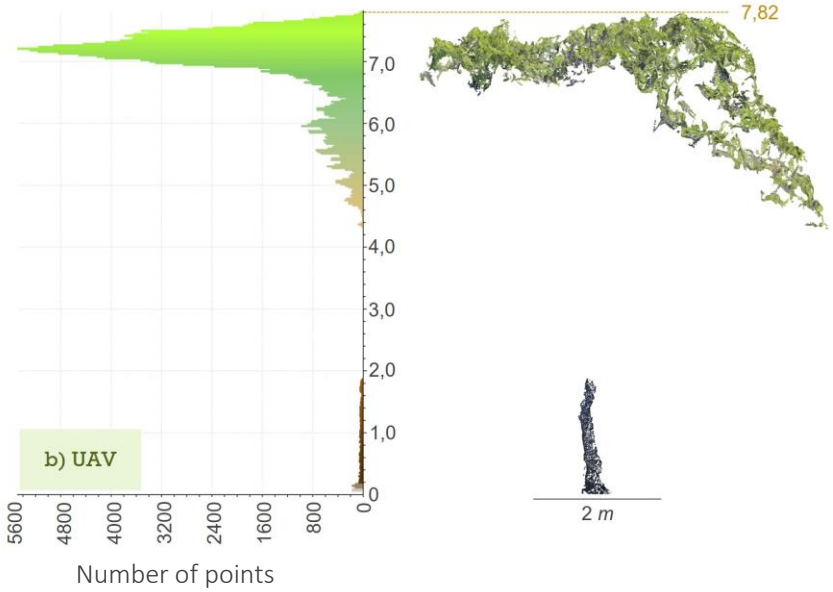


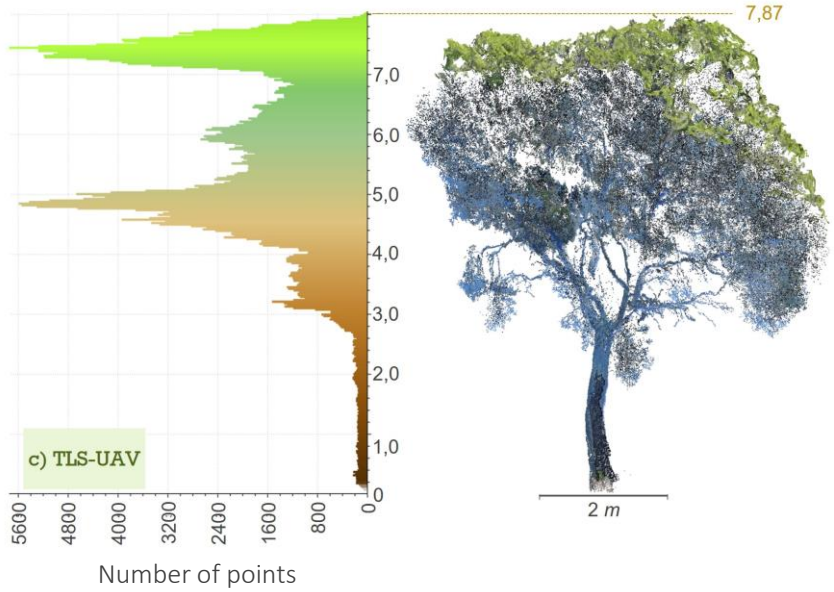
Results and Discussion. *Automatic tree detection*

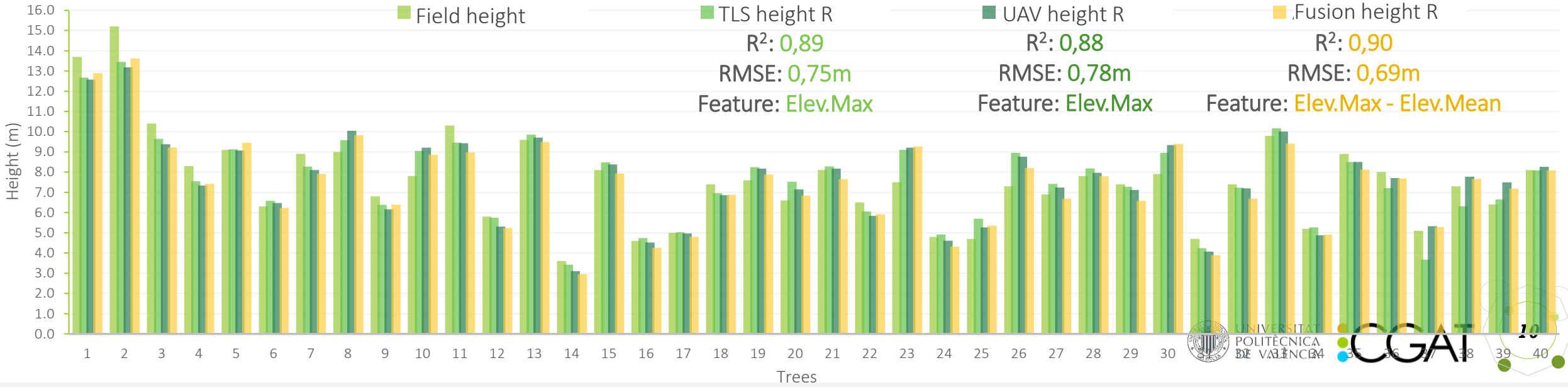


Results and Discussion. *h - Linear regression*





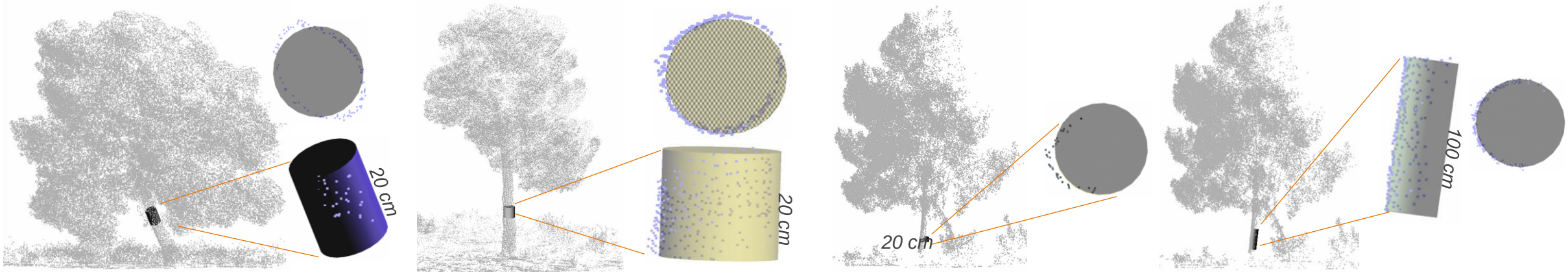




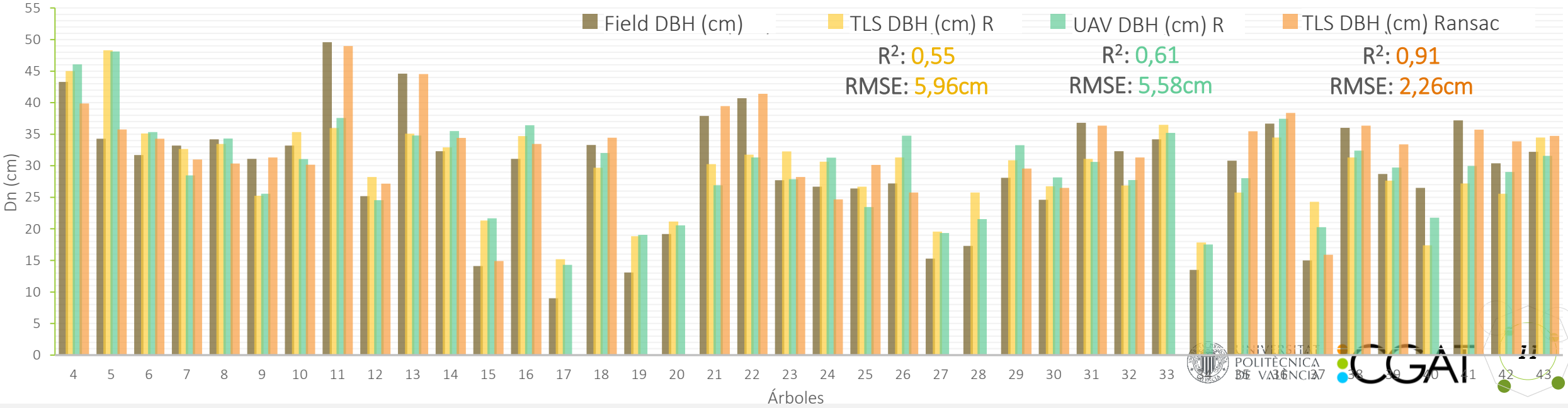
Results and Discussion. *DBH*

RANSAC

80% of the trees - R^2_{adj} de 0,91 - RMSE = 2,26 cm



RANSAC – Lineal Regresion



Results and Discussion. *AGB and VCC*

Parameter	Method	R^2	RMSE	Feature
AGB_TLS_R[1]	Regression	0,47	103,20 kg	Elev.max., Elev.mean
AGB_UAV_R[1]	Regression	0,52	99,54 kg	Elev.max.,
AGB_Fusion_R[1]	Regression	0,54	95,22 kg	Elev.max., Elev.mean, Elev.moda
AGB_TLS_E[3]	Allometric Eq.	0,91	42,23 kg	-
AGB_UAV_E[3]	Allometric Eq.	0,70	65,40 kg	-
VCC_TLS_R[1]	Regression	0.76	62.86 dm^3	Elev.max., Elev.mean
VCC_UAV_R[1]	Regression	0.80	57.32 dm^3	Elev.max.,
VCC_Fusion_R[1]	Regression	0.81	58.07 dm^3	Elev.max.,
VCC_TLS_E[3]	Allometric Eq.	0,91	35,92 dm^3	-
VCC_UAV_E[3]	Allometric Eq.	0,82	54,29 dm^3	-
VCC_Fusion_E[3]	Allometric Eq.	0,92	32,66 dm^3	-

[1]**R** = Regression, [2]**Ra** = Ransac y [3]**E** = Allometric equation

Conclusions

- **Feasibility to use UAV data, TLS, and combining both** to extract different dendrometric characteristics of *Pinus halepensis* in open Mediterranean forests.
- ***height*** - **Accurate results were obtained for all three data sets** with the multiple regression models based on height metrics. However, more significant errors are expected with TLS in denser forests.
- ***DBH RANSAC*** - The measurement is accurate. The **main factors affecting accuracy** are **occlusion generated by canopy structure and sensor-tree distance**. This may limit the efficiency of the method in areas of dense vegetation.
- The proposed method of extracting dn from **the TLS point cloud to estimate AGB and VCC with allometric functions improves accuracy over models based on height metrics**.
- **TLS and UAV point cloud fusion improve VCC estimation**.

Future work will evaluate the performance of the methodology in other forest densities.

Acknowledgments

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Чооң рахмат!

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