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CGAT Grupo de Cartografía GeoAmbiental y Teledetección

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Mapping Fuel Variables in Mediterranean Forests by Terrestrial Laser Scanning: Preliminary Studies

Jesús Torralba, Luis A. Ruiz, Pablo Crespo-Peremarch, Alfonso Fernández-Sarría

Geo-Environmental Cartography and Remote Sensing Group, Universitat Politècnica de València, Camino de Vera, s/n, 46022 Valencia, Spain.

jetorpe@upv.es

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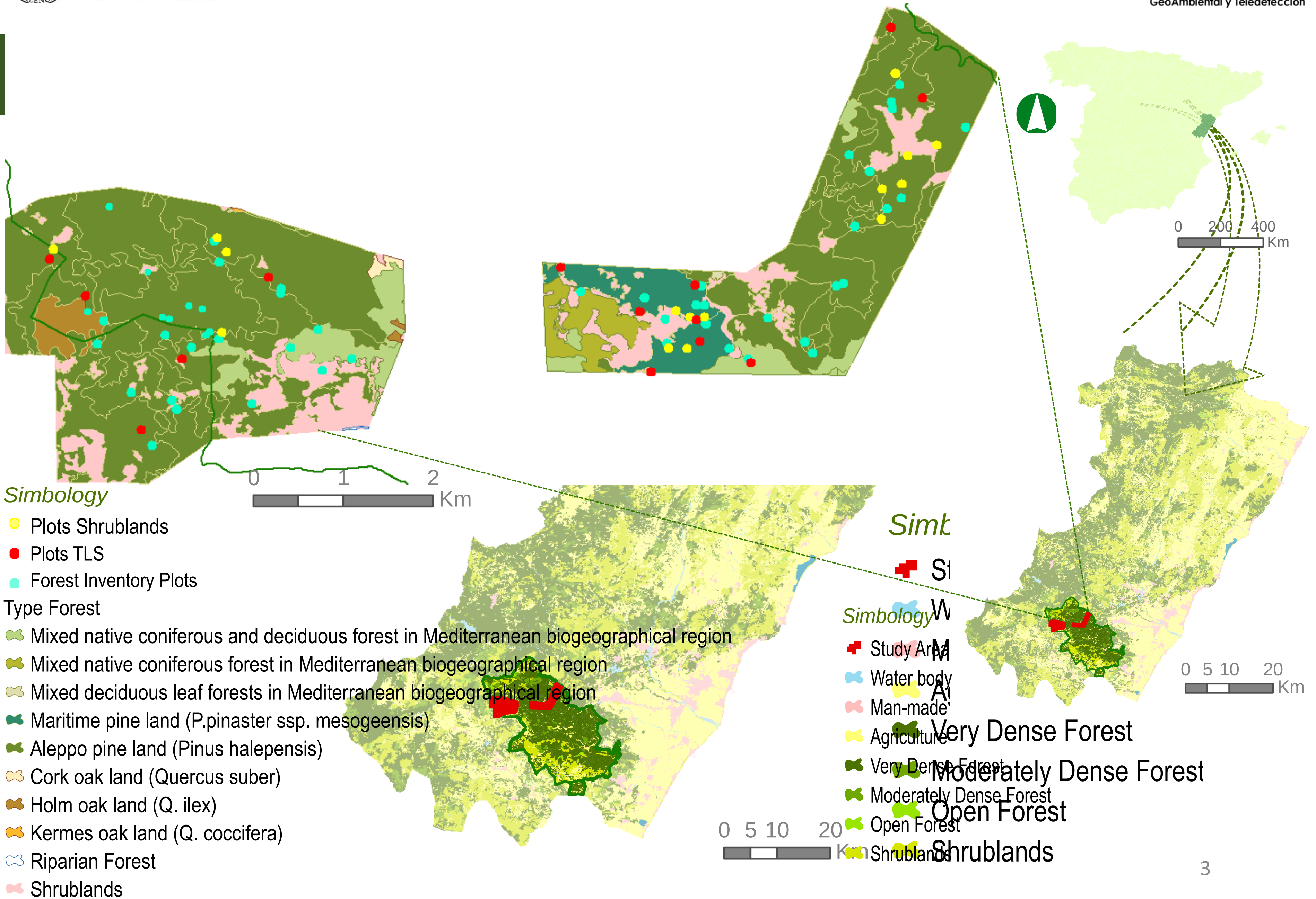
Introduction

Knowledge of the structure and fuel properties of forests is crucial in the prevention and extinction of forest fires.

Terrestrial Laser Scanning (TLS) data have been exploited for the study of the tree component (García *et al.*, 2011; Othmani *et al.*, 2013; Olschofsky *et al.*, 2016; Crespo-Peremarch and Ruiz, 2017; Grau *et al.*, 2017), but to a much lesser extent to analyze the presence, density and composition of **understory** species, of great relevance in Mediterranean forests.

Thesis *(FIRMACARTO Project):* Develop methodologies to estimate variables of the structure of the fuel present in the Mediterranean forest from TLS point clouds. Main Objectives:

(i) Study the optimal distribution of TLS data acquisition;
(ii) Explore the substitution of field measurements by TLS measurements for structure data collection;
(iii) Estimate fuel and structure variables by combining TLS data with aerial LiDAR, Unmanned Aerial Vehicle (UAV) and satellite imagery.


0 200 400 Km
0 1 2 Km
Simbology
Plots Shrublands
Plots TLS
Forest Inventory Plots
Type Forest
Mixed native coniferous and deciduous forest in Mediterranean biogeographical region
Mixed native coniferous forest in Mediterranean biogeographical region
Mixed deciduous leaf forests in Mediterranean biogeographical region
Maritime pine land (P.pinaster ssp. mesogeensis)
Aleppo pine land (Pinus halepensis)
Cork oak land (Quercus suber)
Holm oak land (Q. ilex)
Kermes oak land (Q. coccifera)
Riparian Forest
Shrublands
Simbology
Study Area
Water body
Man-made
Agriculture
Very Dense Forest
Moderately Dense Forest
Open Forest
Shrublands
0 5 10 20 Km
0 5 10 20 Km

Study area

Dominant tree species: **Aleppo pine** (Pinus halepensis), **maritime pine** (Pinus pinaster), **cork oak** (Quercus suber) and **holm oak** (Quercus ilex).

Understory species:
Kermes oak (Quercus coccifera),
tree heath (Erica arborea),
brezo (Erica multiflora),
flax-leaved daphne (Daphne gnidium),
mastic (Pistacia lentiscus),
aulaga (Genista scorpius),
wild asparagus (Asparagus acutifolius),
rosemary (Rosmarinus officinalis),
Mediterranean buckthorn (Rhamnus alaternus),
black hawthorn (Rhamnus lycioides),
false olive (Phillyrea angustifolia),
wild madder (Rubia peregrina),
phoenicean juniper (Juniperus phoenica),
common smilax (Smilax aspera),
thyme (Thymus sp.)...





Dataset

TRADICIONAL FOREST INVENTORY DATA

2015

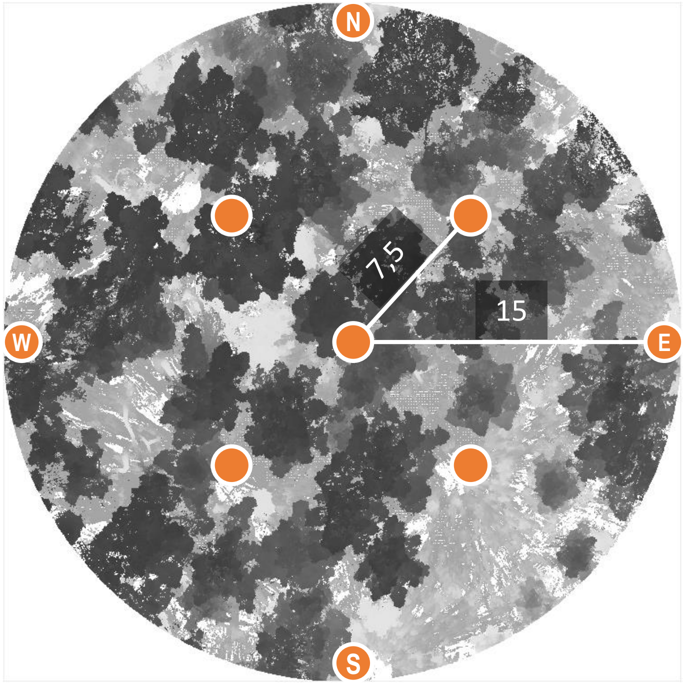
- **80** circular plots (15 m radius)
- Specie, diameter at breast height (DBH), dominate height, canopy base height and qualitative information about plot.

Dataset

TLS DATA

2015

- **28** circular plots (15 m radius)
- Sensor: FARO FOCUS 3D 120
  Accuracy: ± 2 mm at 25 m
  Range: 0,6-120 m
  Pulse frequency: 97 Hz
  Scan angle: Horizontal: 300°
  Vertical: 360°
  Wavelength: 905 nm
  Beam divergence: 0,19 mrad
- 9 scanner positions per plot



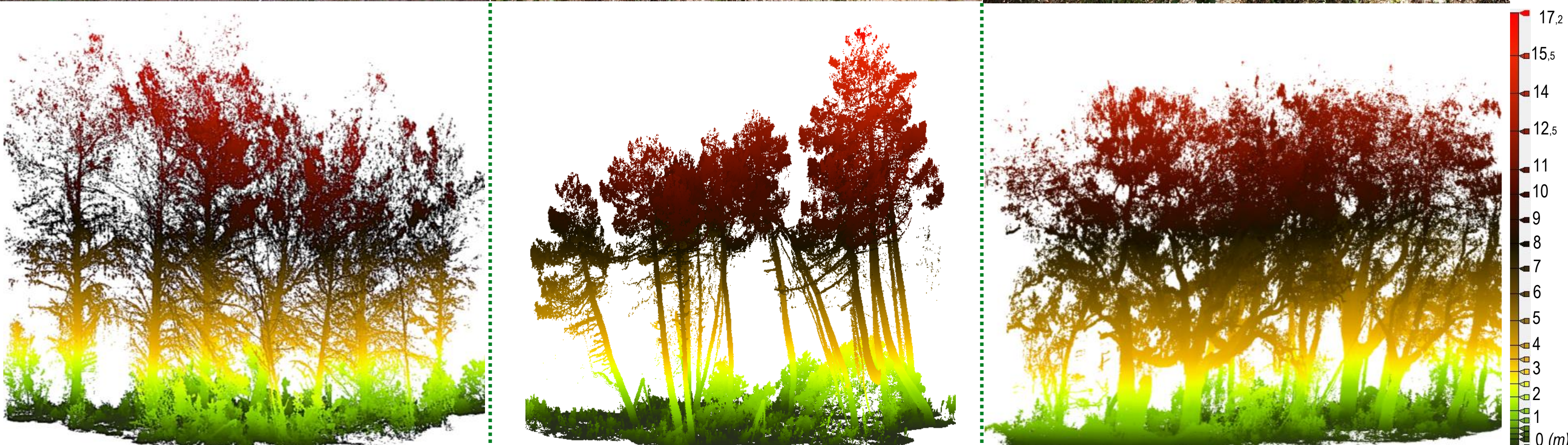
Dataset

TLS DATA (2015)

N=523 $p.ha^{-1}$; AB=26,7 $m^2.ha^{-1}$; QMD=25,5 *cm*; Understory ≈ 50 %

N=637 $p.ha^{-1}$; AB=32,4 $m^2.ha^{-1}$; QMD=25,5 *cm*; Understory ≈ 30 %

N=891 $p.ha^{-1}$; AB=50,5 $m^2.ha^{-1}$; QMD=26,9 *cm*; Understory ≈ 45 %

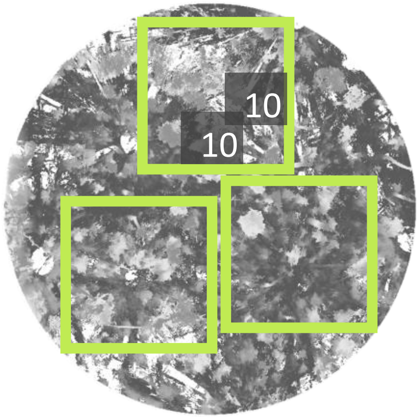


Dataset

TRADICIONAL FOREST INVENTORY DATA

2018

- **35** square sub-plots (10x10 m)
- Measurement all trees and **understory vegetation** in the plot
- Position, specie, principal length of the understory, medium height understory, and vertical fuel continuity between the understory and canopy.



Methods

(i) Define the **layout** and **optimal number of TLS** scanners to **characterize the forest structure** in the study area.

(ii) Explore the **substitution** of **field measurements by TLS** measurements for structure data collection

(iii) Estimate **fuel and structure variables** by combining TLS data with aerial **LiDAR**, **Unmanned Aerial Vehicle** (UAV) and **satellite imagery**.

Methods

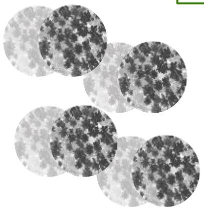
(i) Define the layout and optimal number of TLS scanners to characterize the forest structure in the study area.

FOREST INVENTORY DATA

Forest Inventory (DBH, H, h1, specie)

Forest and Fuel Parameters: Density, Basal area, Stand Density Index, Canopy Height, Canopy Base Height, Volume or Biomass…others?

TLS DATA

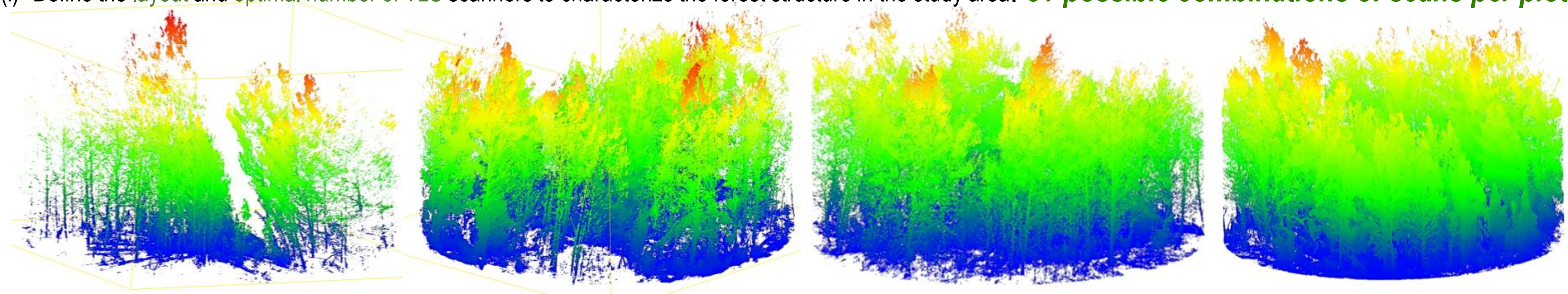


$$\frac{\text{28 plots}}{\text{9 scanners/plots}}$$

31 possible combinations of scans per plot

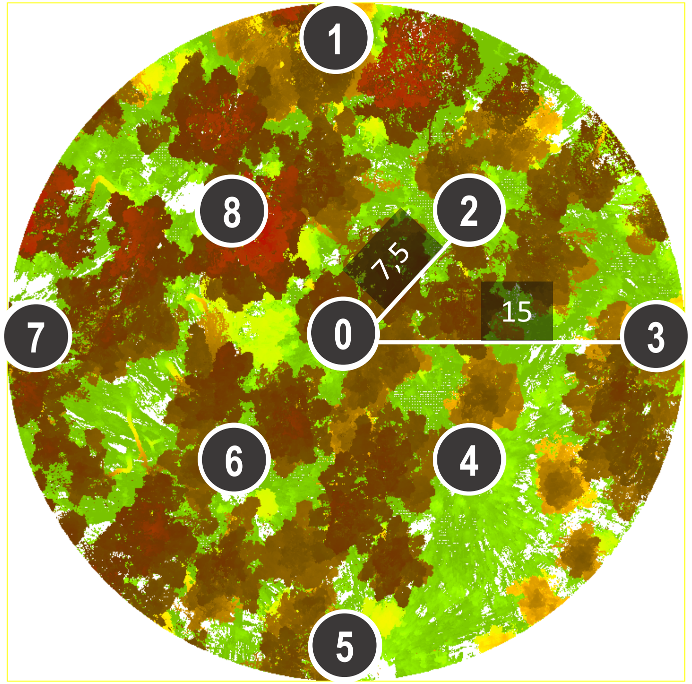
Methods

(i) Define the layout and optimal number of TLS scanners to characterize the forest structure in the study area. ***31 possible combinations of scans per plot***



Combination of TLS data acquisition proof:

Nº	Combination	Nº	Combination
1	0	11	275
2	15	12	307
3	26	13	315
4	37	14	368
5	48	15	408
6	105	16	417
7	137	17	426
8	146	18	528
9	206	19	537
10	248	20	631



Combination of TLS data acquisition proof:

Nº	Combination
21	648
22	715
23	724
24	826
25	835
26	01357
27	1357
28	02468
29	2468
30	12345678
31	012345678

Methods

(i) Define the layout and optimal number of TLS scanners to characterize the forest structure in the study area.

FOREST INVENTORY DATA

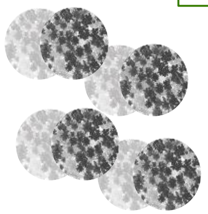
Forest Inventory (DBH, H, h1, specie)

↓

Forest and Fuel Parameters: Density, Basal area, Stand Density index, Canopy Height, Canopy Base Height, Volume or Biomass…others?

↓

TLS DATA



28 plots

9 scanners/plots

↓

31 possible combinations of scans per plot

↓

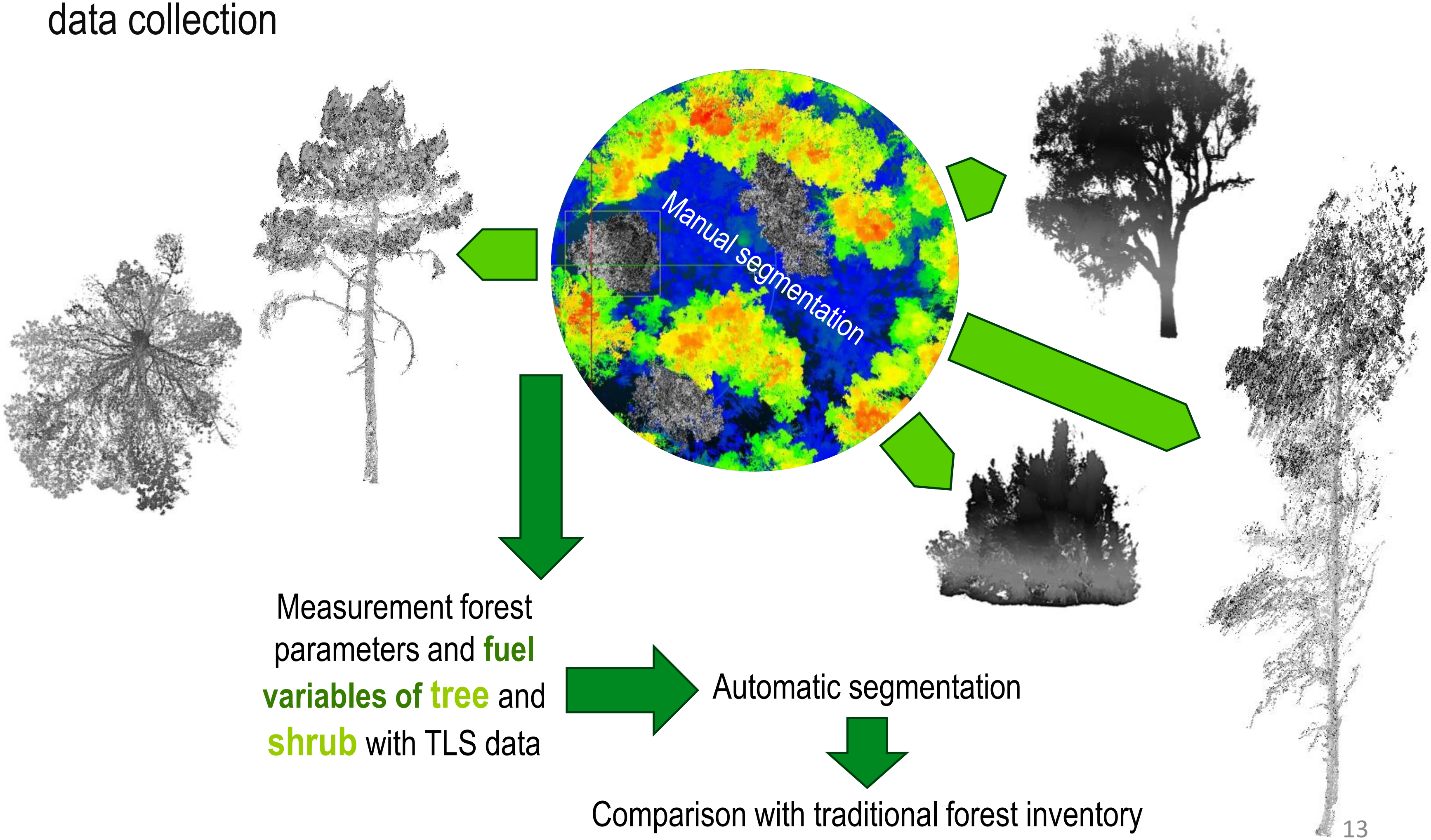
LiDAR Statistics parameters: Number of returns, Minimum, Maximum, Mean, Variance, Skewness, Kurtosis, Percentile values of height/intensity, L-moments, etc.

↓

Multiple Linear Regression Models

Methods

(ii) Explore the **substitution** of **field measurements by TLS** measurements for structure data collection



Methods

(iii) Estimate **fuel and structure variables** by combining TLS data with aerial **LiDAR**, **Unmanned Aerial Vehicle** (UAV) and **satellite imagery**.

Plot — **TLS**

↓ *Structural parameters and fuel variables*

Stand — **UAV**

↓ *Horizontal and vertical fuel continuity between the understory and canopy*

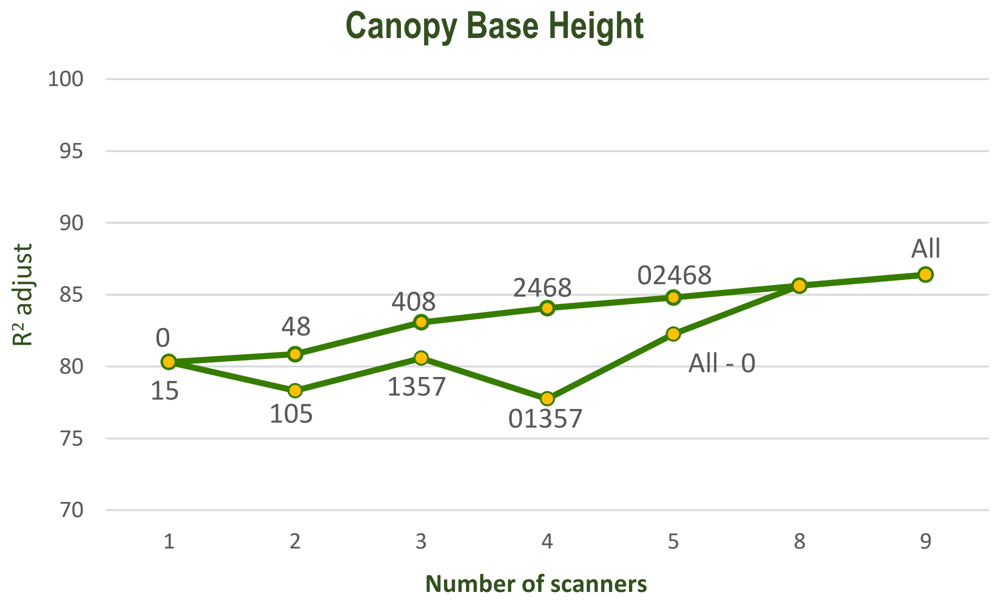
Forest Type — **ALS**

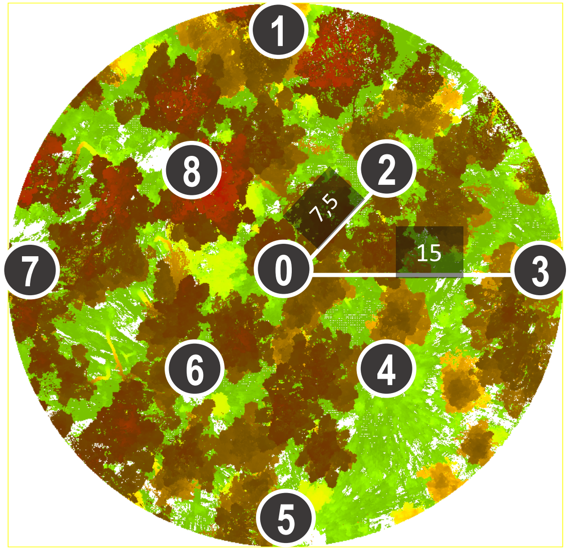
↓

Forest — **Satellite imagines** — *Extrapolation of variables to large forest areas*

Initial Results

(i) Layout and optimal number of TLS scanners to characterize the Canopy Base Height (CBH)





Initial Results

(i) Layout and optimal number of TLS scanners to characterize the Canopy Base Height (CBH)

Nº of scanners	Combination	R^2	R^2 adjust	Standard error of the estimate	Errors Absolute Medio	Durbin-Watson P	P	Equation
1	0	81,7700	80,3120	0,983756	0,809702	1,92769	0,395	CBH = -5.43731 + 1.51091*Elev P90 - 0.160047*Elev variance
2	15 (15m)	79,9263	78,3204	1,03221	0,851232	1,501	0,0823	CBH = 0.16692 + 0.895294*Elev P95 + 0.752097*Int L3
2	48 (7.5m)	82,2731	80,8550	0,969998	0,790505	1,93767	0,4337	CBH = 2.1379 + 0.860278*Elev P95 - 0.162212*Percentage all returns above mean
3	105	82,0224	80,5842	0,976833	0,751944	1,96452	0,4441	CBH = -2.22051 + 1.05322*Elev P90 + 1.09243*Int skewness
3	408	84,3325	83,0791	0,911917	0,714354	1,90444	0,3903	CBH = 1.45949 + 0.979735*Elev P90 - 0.142486*Percentage all returns above mea
4	1357	79,3979	77,7497	1,04571	0,751699	1,71324	0,2066	CBH = -3.43471 + 1.84995*Elev P90 - 2.31383*Elev AAD
4	2468	85,2466	84,0663	0,884913	0,732275	1,92536	0,4252	CBH = 0.91465 + 0.941089*Elev P95 - 0.147174*Percentage all returns above mean
5	13570	83,572	82,2578	0,933785	0,717896	1,85257	0,3263	CBH = -3.64394 - 4.76475*Elev L2 + 2.09978*Elev P90
5	24680	85,9256	84,7997	0,86431	0,636323	1,83204	0,3183	CBH = 1.17013 + 1.0172*Elev P90 - 0.141901*Percentage all returns above mean
8	12345678	86,6858	85,6207	0,840643	0,630868	1,81732	0,3018	CBH = 3.2861 + 0.978986*Elev P90 - 0.203896*Percentage all returns above mean
9	123456780	87,4054	**86,3979**	0,81761	0,583844	1,83486	0,3193	CBH = 2.55755 + 1.01557*Elev P90 - 0.190265*Percentage all returns above mean

Acknowledgments

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Geo-Environmental Cartography and Remote Sensing Group
Department of Cartographic Engineering, Geodesy and Photogrammetry
Universitat Politècnica de València, España