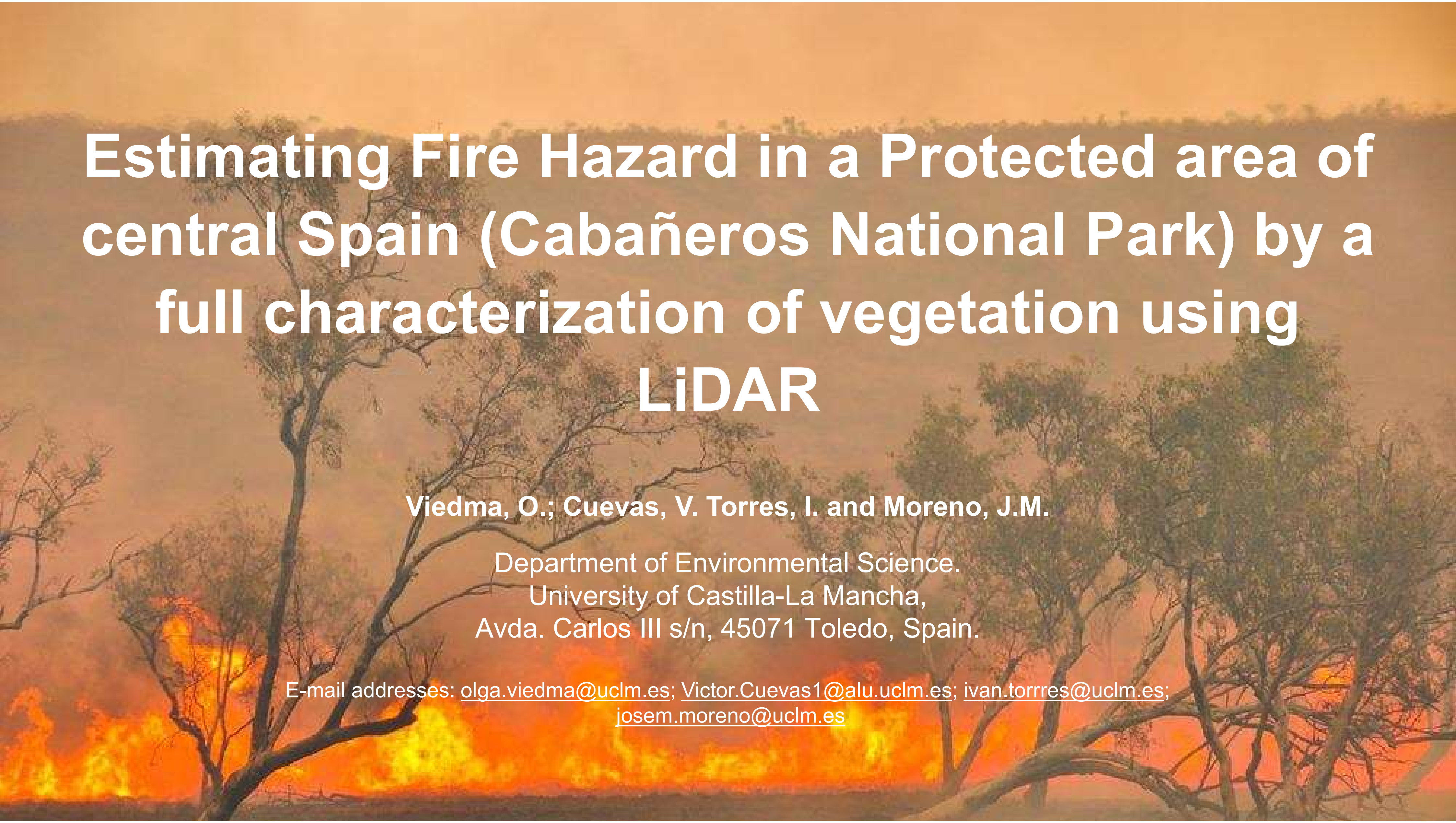

Estimating Fire Hazard in a Protected area of central Spain (Cabañeros National Park) by a full characterization of vegetation using LiDAR

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University of Castilla-La Mancha,
Avda. Carlos III s/n, 45071 Toledo, Spain.

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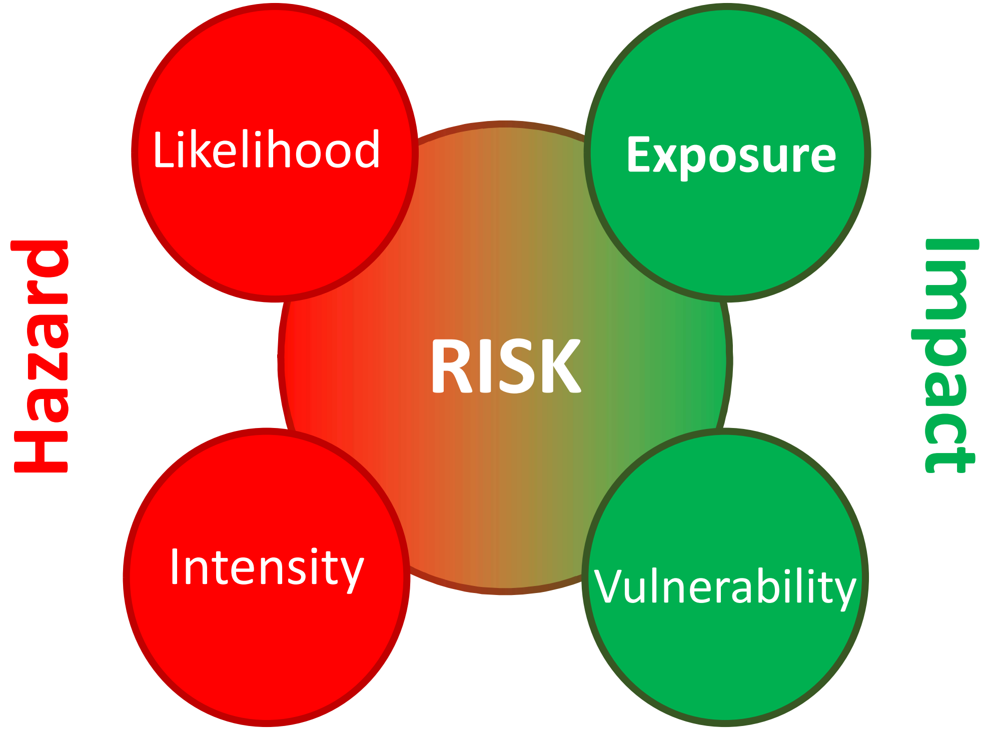
INTRODUCTION

FIRE RISK AND VULNERABILITY

The main objective of **fire risk analysis** is to estimate the **probability of exposure** of high value resources and assets **to forest fires at different levels of intensity** and **to predict the responses of these resources and values**. Consequently, forest fire risk can be defined as the **multiplicative interaction** between the **hazard** (probability and intensity of a fire) and its **impact** (exposure and vulnerability).



COMPONENTS OF RISK AND VULNERABILITY

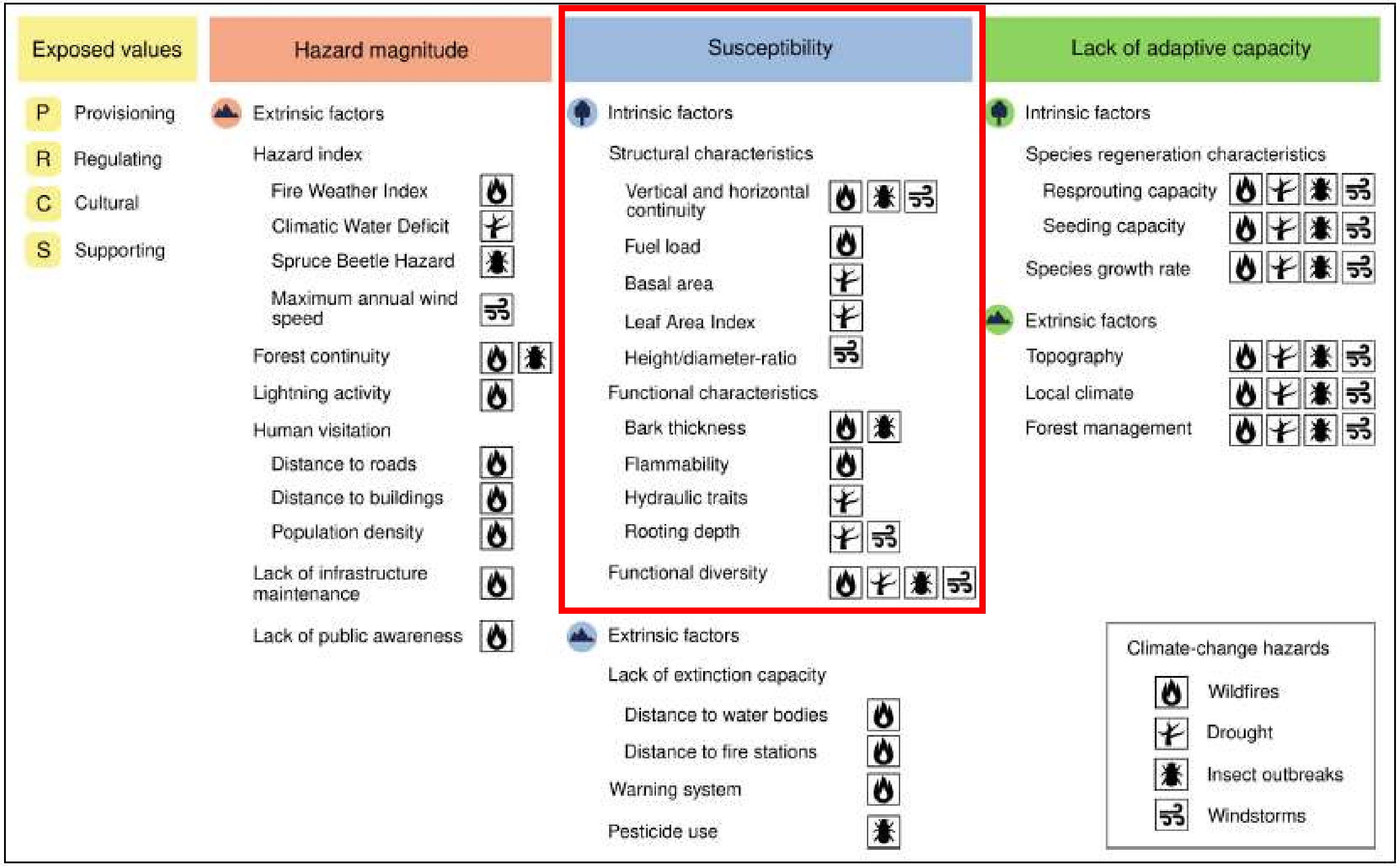


Figure 3. Indicators for each of the components of risk and vulnerability for the four main climate-change hazards considered in this study (wildfires, drought, pests, and windstorms).

Source: Lecina-Diaz et al. 2020 ***Front Ecol Environ*** 2021; 19(2): 126–133, doi:10.1002/fee.2278

OBJECTIVES

Main Objective:

1. To classify the landscape by:
   - its "**fire hazard**" using the **Fuel Models** (FMs) as framework
   - its "**resistence**" and "**resilience**" to forest fires as main disturbance using **plant functional traits**

Specific Objectives:

1. To **pre-process adequately LiDAR data** to derive **forest metrics** as accurate as posible. Sensitivity analysis of filter algorithms to classify the points cloud (ground-no ground).

2. To **develop FMs complexes** to characterize the structure, the composition and the moisture content of vegetation (at both **pixel** and **polygon** scales).

3. To **link the developed FMs with standard FMs** as those done by **Scott and Burgan** (2005) and Rothermel (1972).

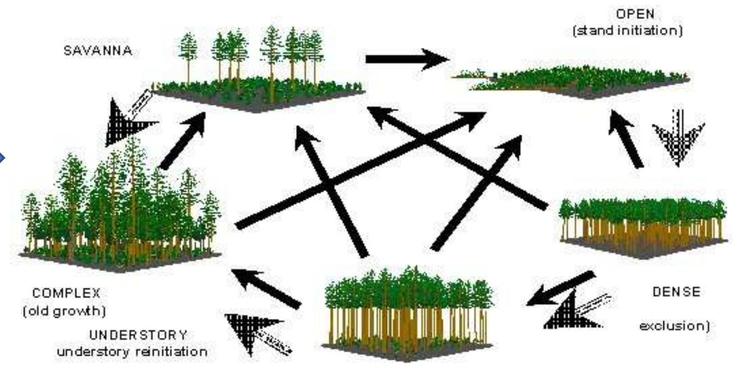
4. To **carry out fire spread simulations at landscape scale** based on the FMs using the **FLAMMAP** soft.

MATERIAL AND METHODS

LIDAR DATA

- FCC (total, trees, understory)
- Height statistics
- Total and by vegetation strata:
  Low (< 1m); Medium (1-2m); Tall (2-4m)

Vegetation structure

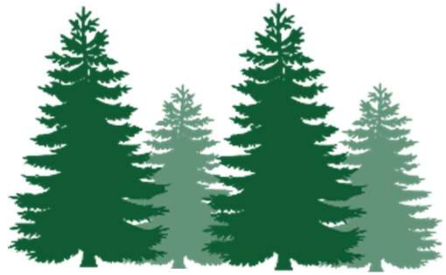


NATURAL VEGETATION SYSTEMS MAP

Community types:

- Grasses
- Shrubs
- Forests (conifers, broadleaved: evergreen-deciduous)

Vegetation composition



NATIONAL FOREST MAP + AUXILIARY DATA

Dominant species (first three ones)

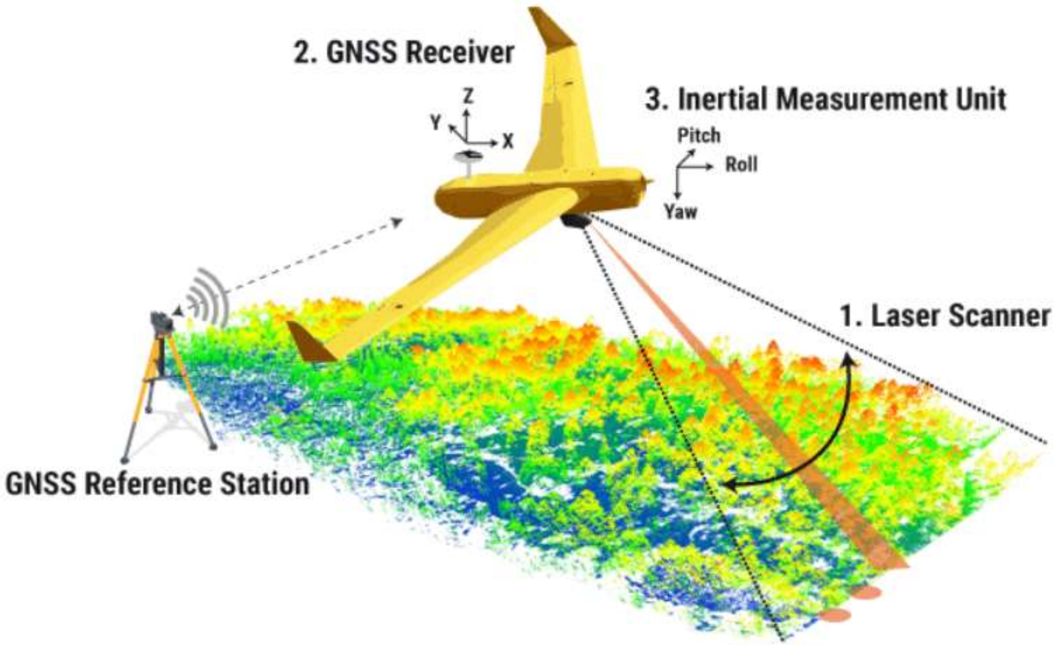
Functional traits: resistence and resilience to forest fires

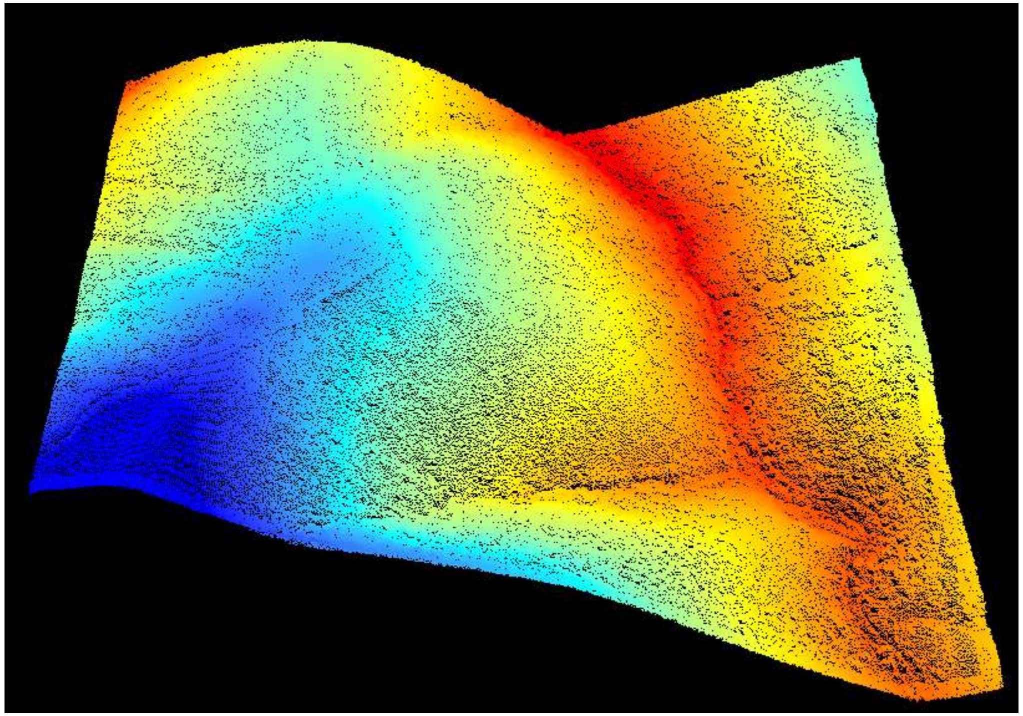
Flammability

MATERIAL

LIDAR DATA

1. **The LiDAR sensor** responsible for the emission and reception of the laser pulse, measurement of the reading angle and the time it takes for the emitted pulse to reflect on a surface.
2. **The Global Positioning System (GPS-GNSS)** whose function is to determine the x, y, z coordinates of the LiDAR sensor during its trajectory together with a GPS ground station.
3. **The inertial measurement unit (IMU)** measures the heading of the aircraft. This is combined with the LiDAR sensor, which establishes the angular orientation for each pulse.

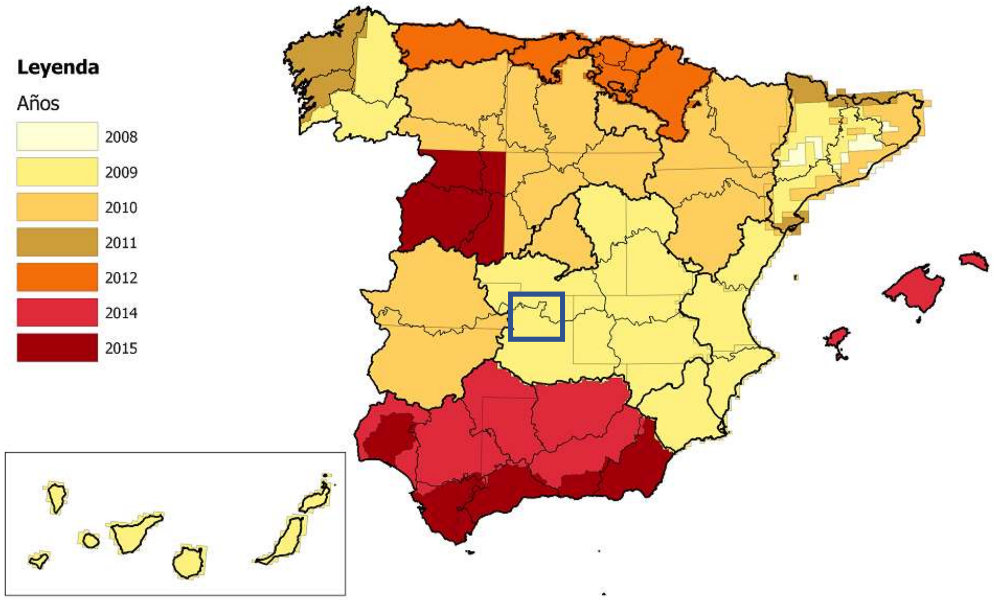




MATERIAL

SPANISH LIDAR DATA (since 2008)

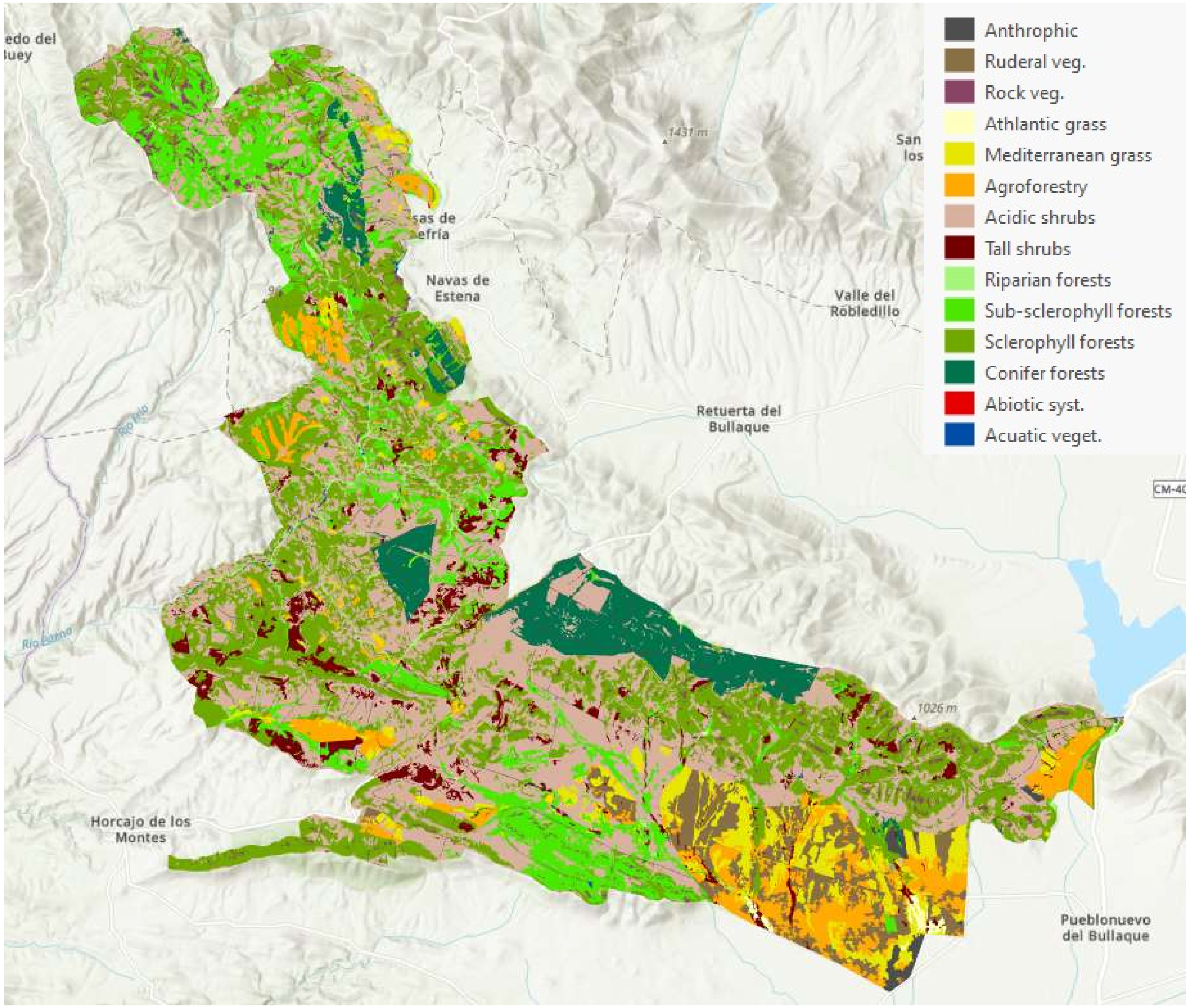
TECHNICAL SPECIFICATIONS LiDAR PNOA	
Density (points/m2)	**0,5-1**
Point spacing (m)	1,41
LiDAR sensor	ALS 50 – II
FOV (º)	50
PRF (kHz)	70 min
Sweep Frequency (Hz)	70Hz
Speed (knots)	148
Speed (Km/h)	274
Transversal overelapping (%)	15
Altimetric discrepancy between passes	≤ 0,40 m
RMSE	≤ 0,20 m
Distance to reference stations	≤ 40 km
Spectral resolution	8 bits
GPS	min. 2Hz
Pixel size (spatial resolution)	**0,25 m**
Maximum length of a longitudinal pass	4 tiles from MTN 50



MATERIAL

NATURAL VEGETATION SYSTEMS MAP

Multilevel legend



MATERIAL

NATURAL VEGETATION SYSTEMS MAP

Multilevel legend

Level 1

- cdad_ruderales
- form_arbustivas
- mat_acidofilos
- pastizal_atlantico
- pastizal_mediterraneo
- sist_abioticos
- sist_antropicos
- sist_bosques_coniferas
- sist_bosques_esclerofilos
- sist_bosques_ribera
- sist_bosques_subesclerofilos
- sist_seminaturales
- veg_hidrofila
- veg_rupicola

Level 2

- Agua
- Alcornocales
- Bosque_mixto_esclerófilo
- Bosques_ribera
- Dehesas
- Encinares
- Espinares
- Formaciones_freatofitas
- Herbazales
- Jarales_brezales_maquis
- Madroñales
- Melojares_robledales_rebollares
- Pastizales_diente
- Pastizales_oligotrofos
- Pinares_Pinus_pinaster
- Pinares_Pinus_pinea
- Praderas_juncales
- Quejigares
- Repoblaciones
- Retamares_escobonales_piornales
- Sistemas_agricolas
- Sistemas_artificiales
- Turberas
- Vegetación acuática
- roquedos
- vegetacion_canchales

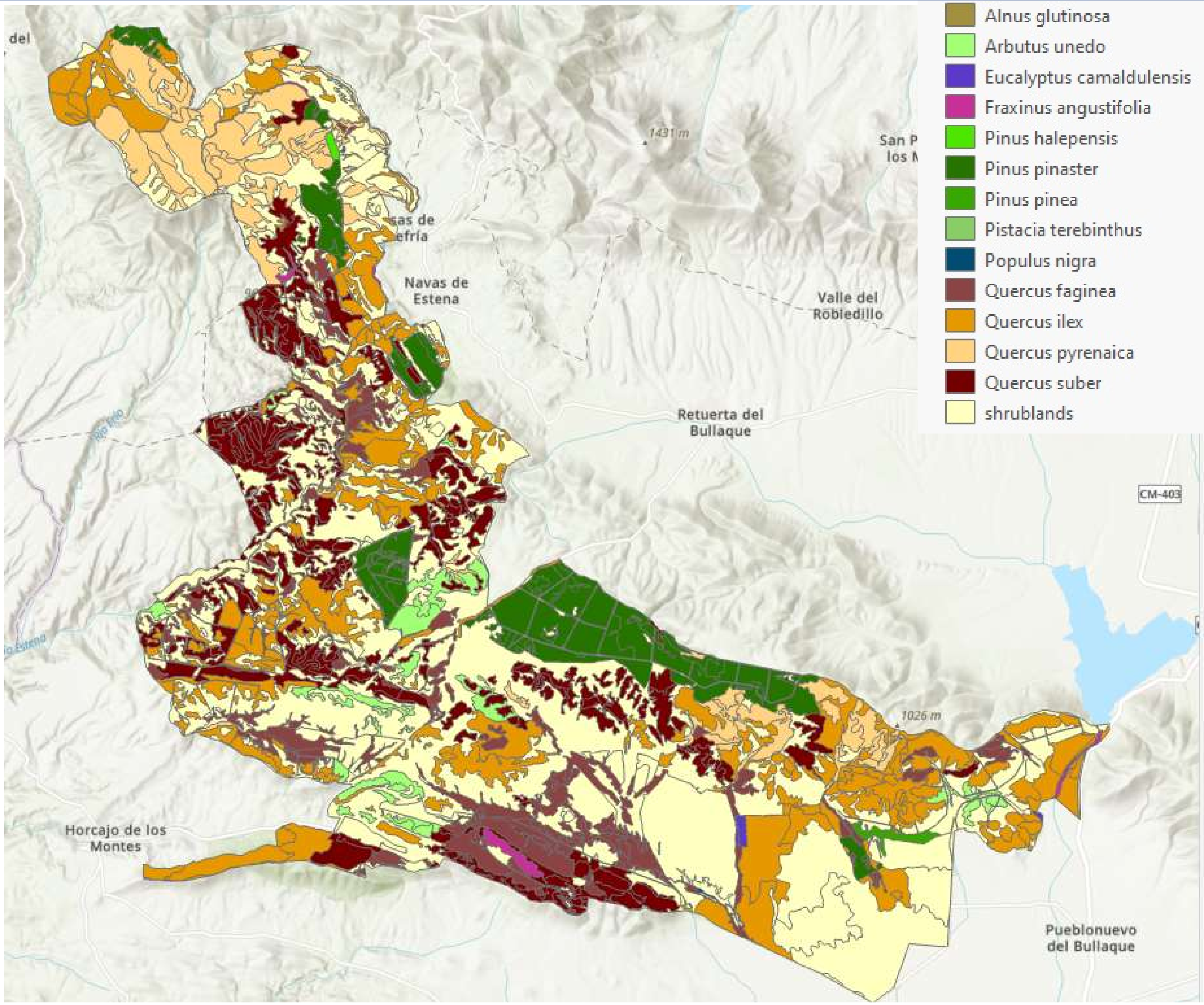
Level 3

- Abedulares meridionales
- Agua
- Alcornocales
- Alisedas
- Brezales enanos
- Brezales higroturbosos
- Brezales negros
- Brezales_Erica_australis
- Choperas
- Cortafuegos
- Cultivos
- Dehesas_Qfaginea
- Dehesas_alcornoque
- Dehesas_encina
- Dehesas_encina_alcornoque
- Encinar_alcornocal
- Encinares_carrascales
- Escobonales
- Fresnedas
- Infraest_viales
- Jarales
- Loreras
- Madroñales
- Melojares
- Pastizales_diente
- Pastos_terofiticos
- Pastos_terofiticos_nitrificados
- Pinares_Pinus_pinaster
- Pinares_Pinus_pinea
- Praderas_juncales
- Quejigares
- Saucedas
- Tamujares
- Vallicares
- Vegetación acuática
- Zarzales
- Zonas_edificadas
- cdades_cantiles
- vegetacion_canchales

MATERIAL

NATIONAL FOREST MAP (2004)

DOMINANT SPECIES
(3 LEVELS)

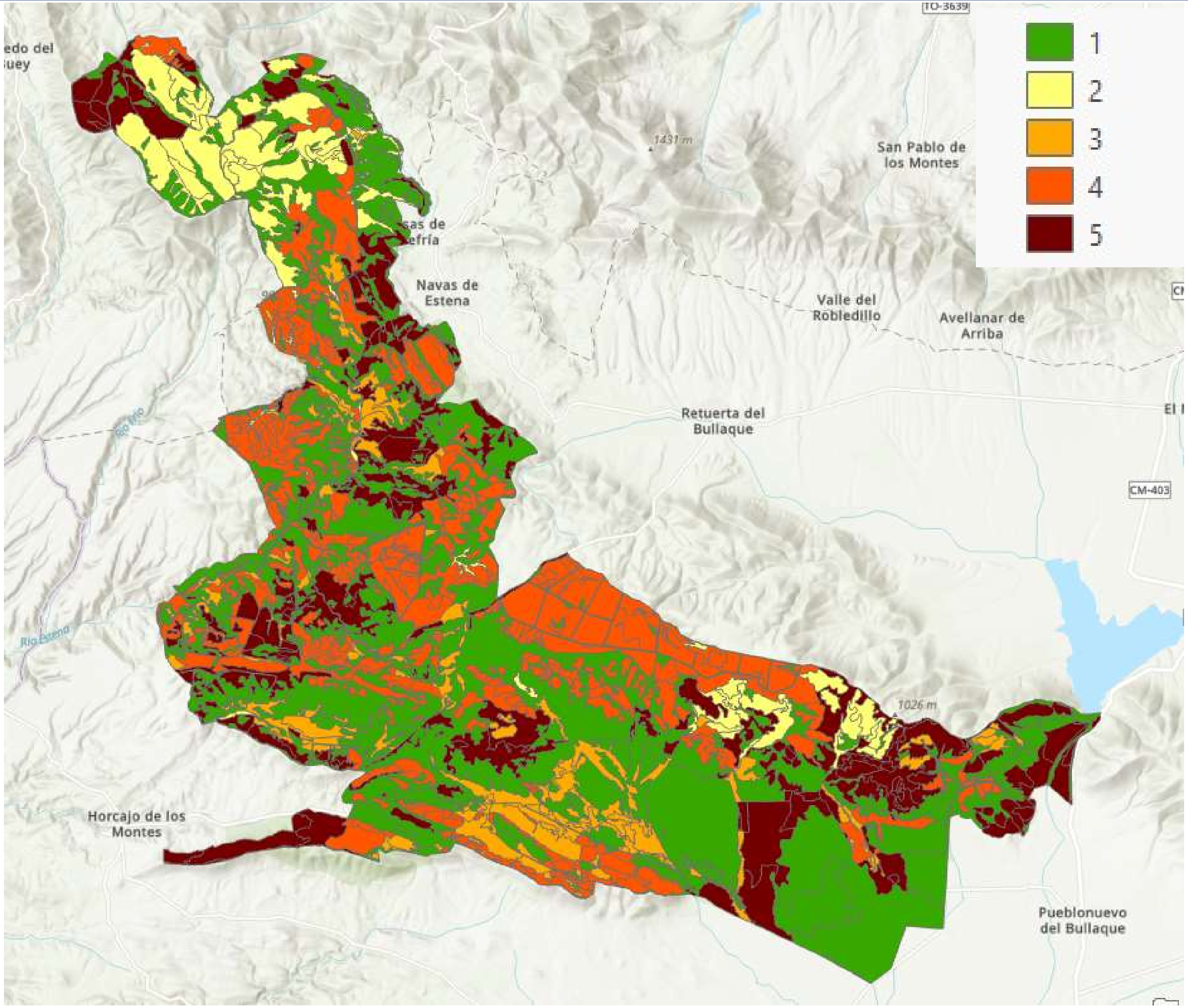


MATERIAL

NATIONAL FOREST MAP (2004)

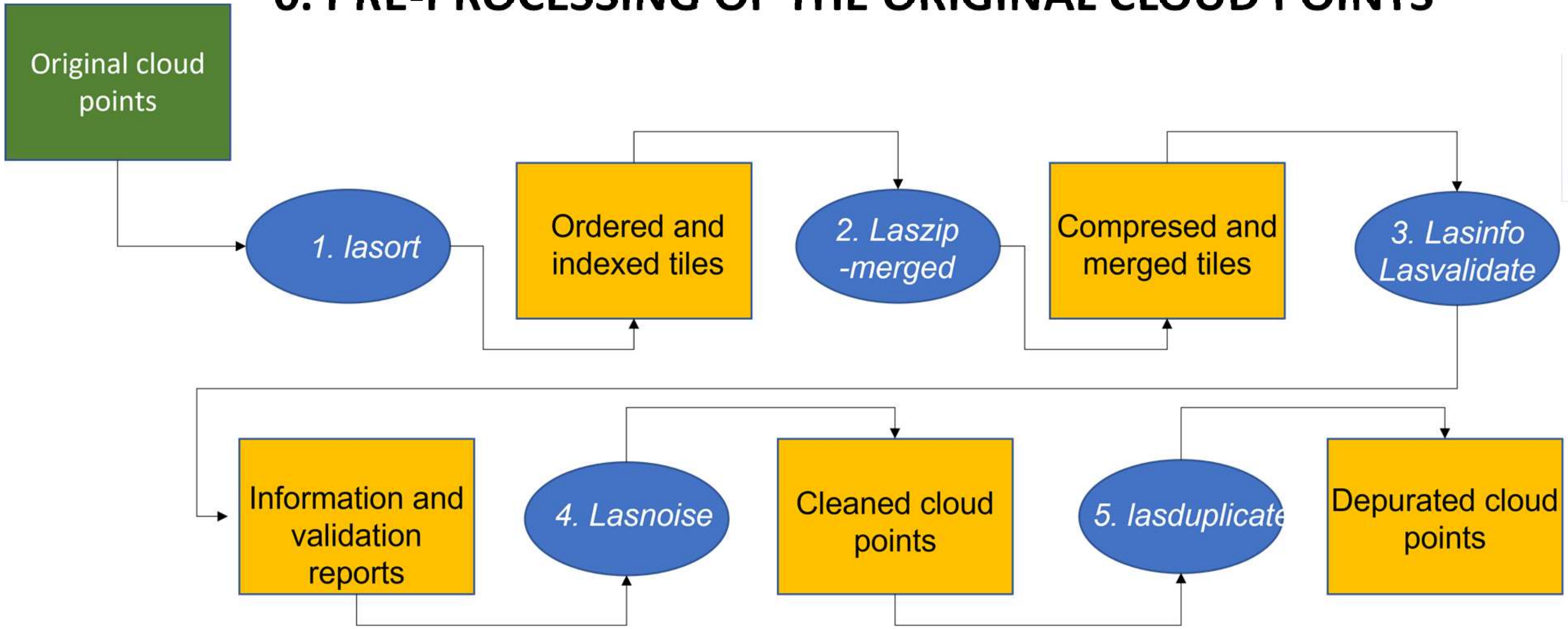
FLAMMABILITY

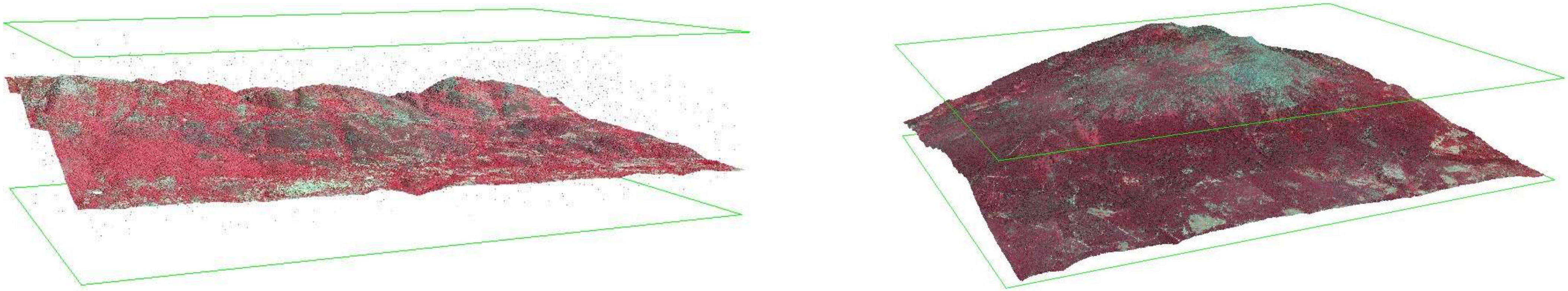
DOMINAT SPECIES



METHODOLOGY

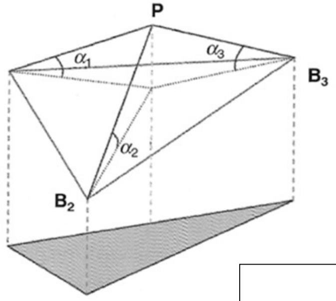
0. PRE-PROCESSING OF THE ORIGINAL CLOUD POINTS





METHODOLOGY

1. CLASSIFICATION OF ORIGINAL CLOUD POINTS: GROUND – NON GROUND



Filter of Progressive densification (TIN)

TIN = Triangular Irregular Networks

Original cloud points

1.lasground_new

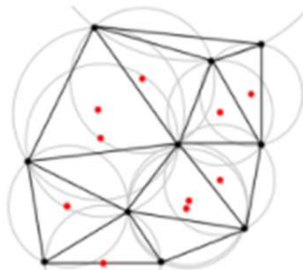
TIN Filters:

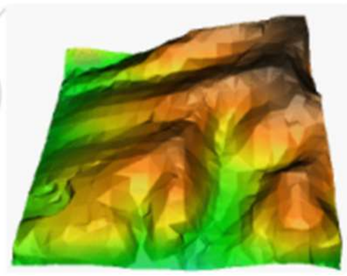
- TOWN
- WILD
- SWITCH
- DEFAULT
- SIOSE

Classification of last returns (**ground – non ground**)

2. Blastdem (TIN)

DEM generation





METHODOLOGY

2. HEIGHT NORMALIZATION

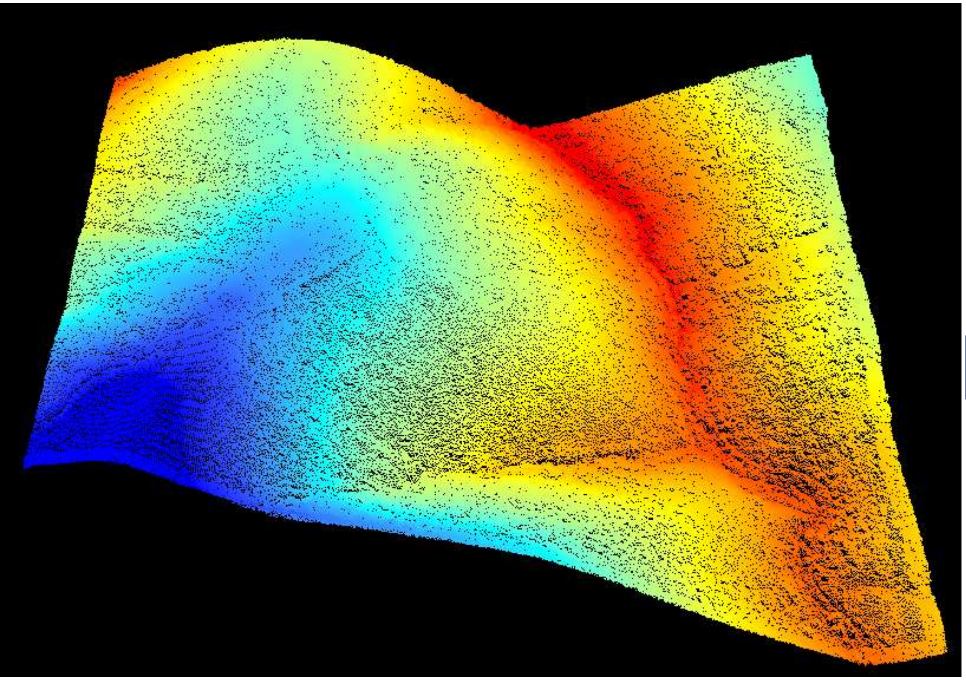
Classified points (ground-non ground)

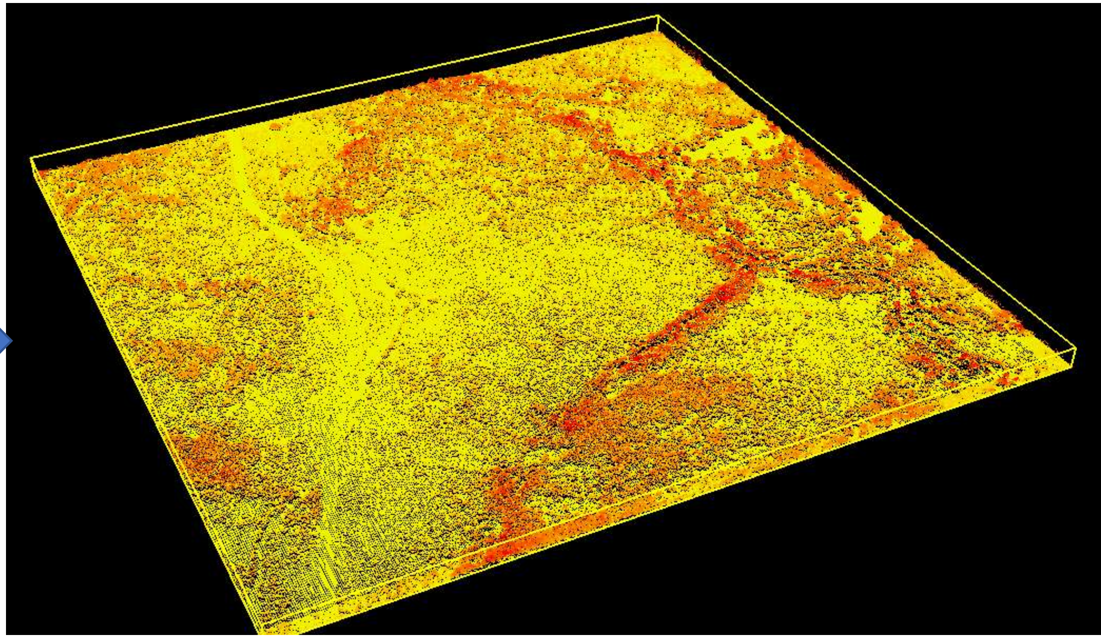
↓

Lasheight –replace_z

↓

NORMALIZED ELEVATION OF THE CLOUD POINTS (MIN= 0)





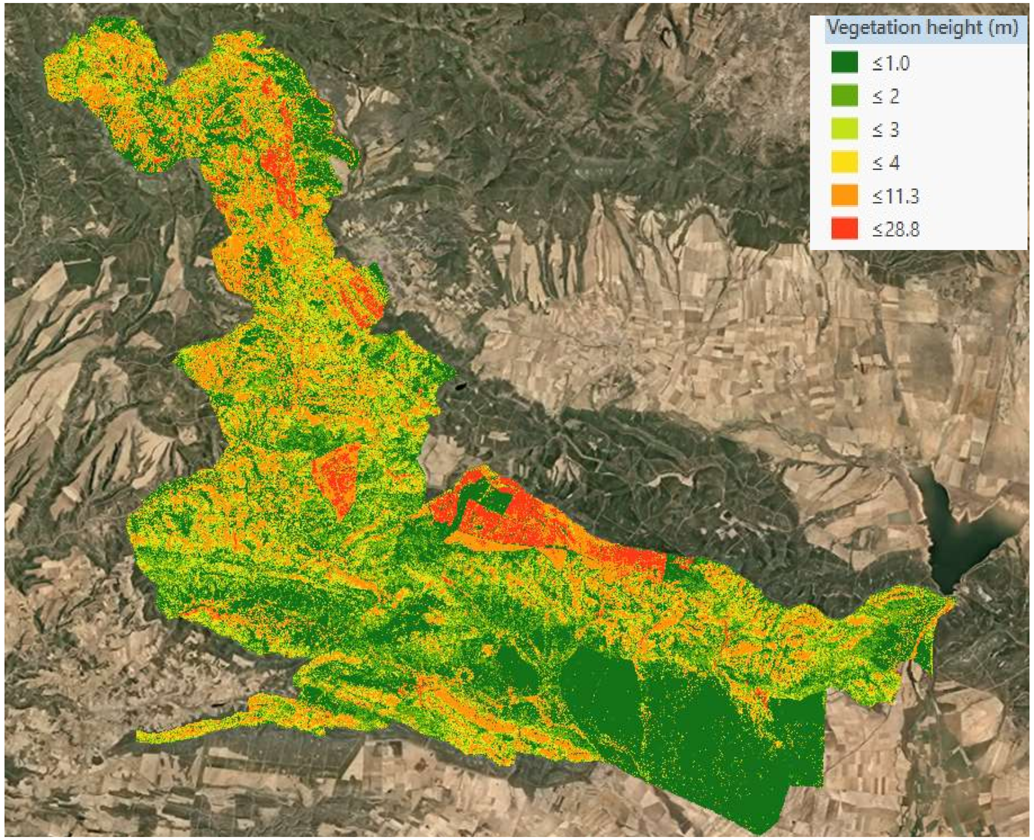
METHODOLOGY

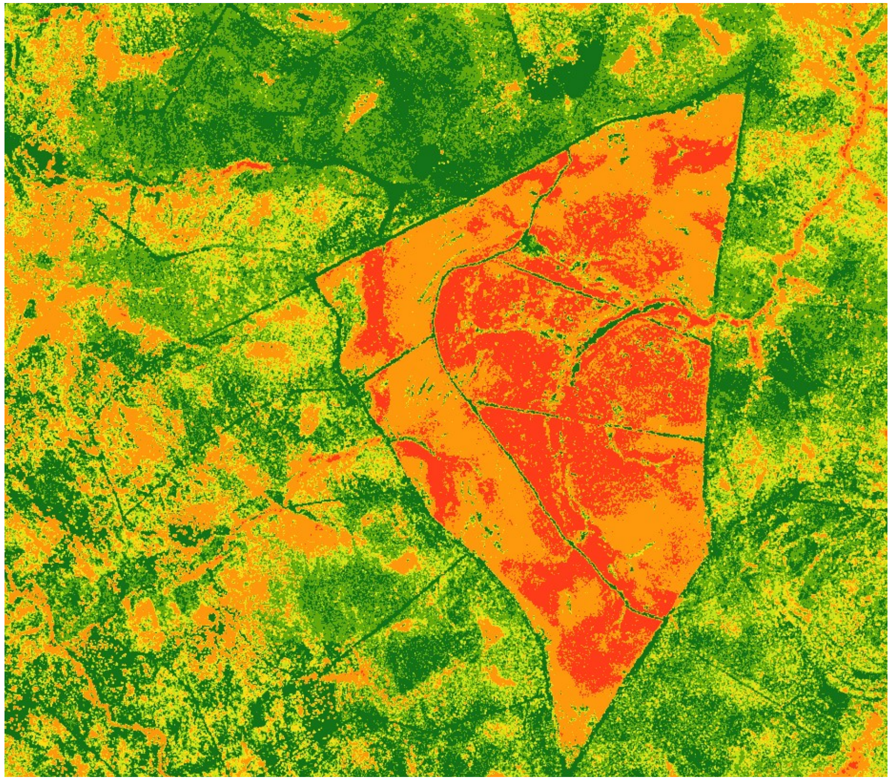
3. PIT-FREE CANOPY HEIGHT MODEL

Normalized elevation of cloud points

⬇

grid_canopy pitfree(0,2,5,10,15,20,30)





METHODOLOGY

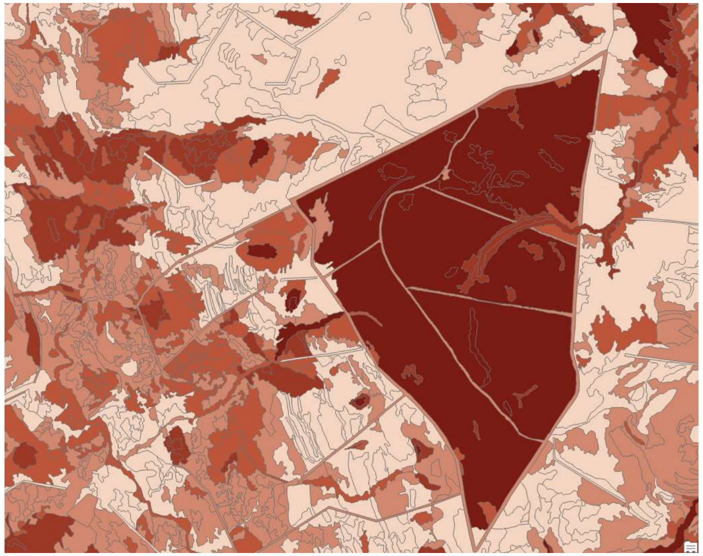
4. VEGETATION METRICS

LasTools

Normalized elevation of cloud points

Lascanopy

At Polygon Scale



At Grid Scale

Fraction Cover estimated by **Height Bins**
(density of points by height thresholds)

Understory
(< 0.3m; < 1m; 1-2m and 2-4m)

Canopy
(> 4m)

Height metrics for Understory and Canopy
(Mean, Max, Min, SD, Percentiles 5-50-90-95)

METHODOLOGY

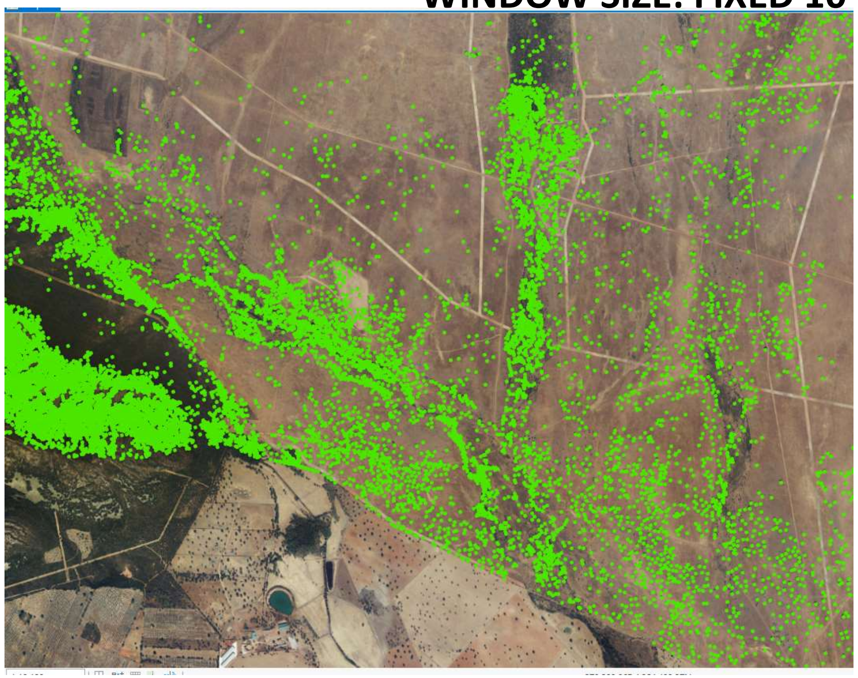
5. TREE TOPS LOCATION

Normalized elevation of cloud points

locate_trees (hmin = 4)

(Different window sizes: adaptative, fixed 5 and 10)

WINDOW SIZE: FIXED 10



METHODOLOGY

6. CROWN METRICS

Tree Tops

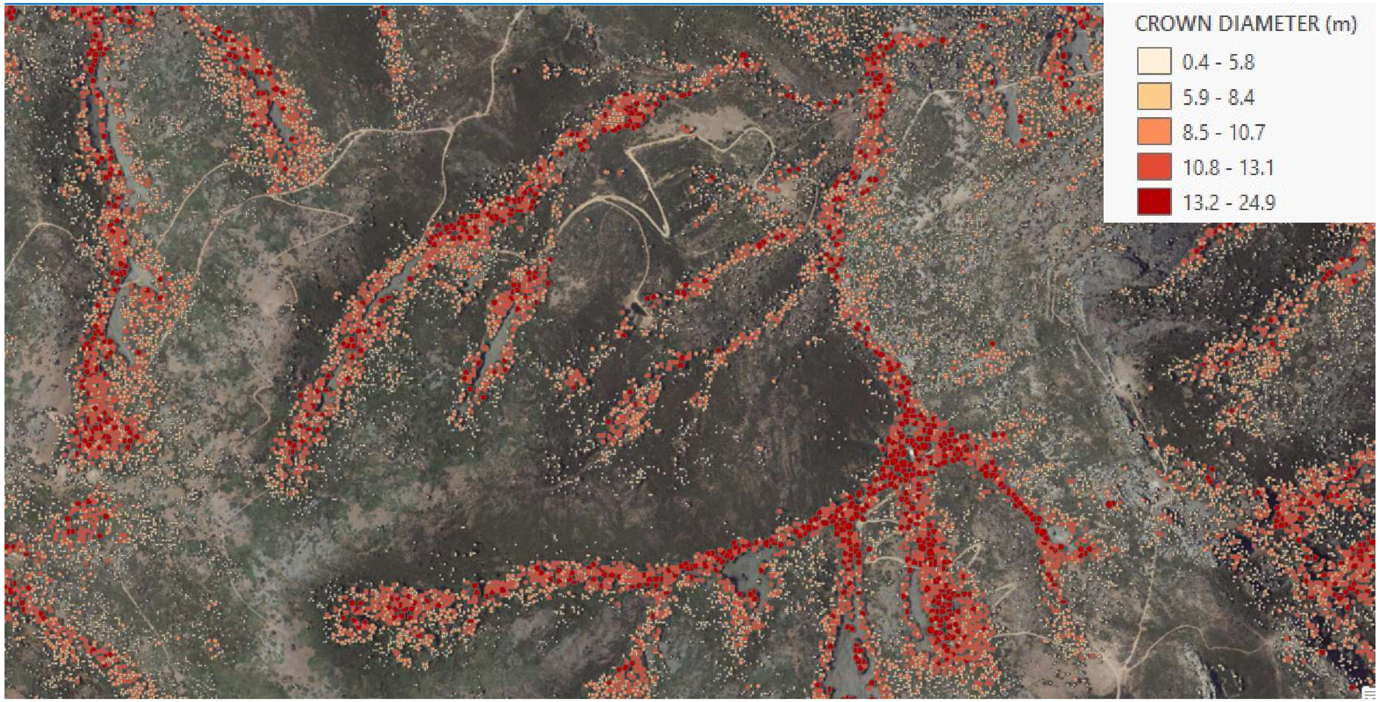
Pit-free Canopy Height Model

segment_trees

(max_cr_factor = 0.6, exclusion = 0.3)

Methods:
Silva, Dalponte, Watershed

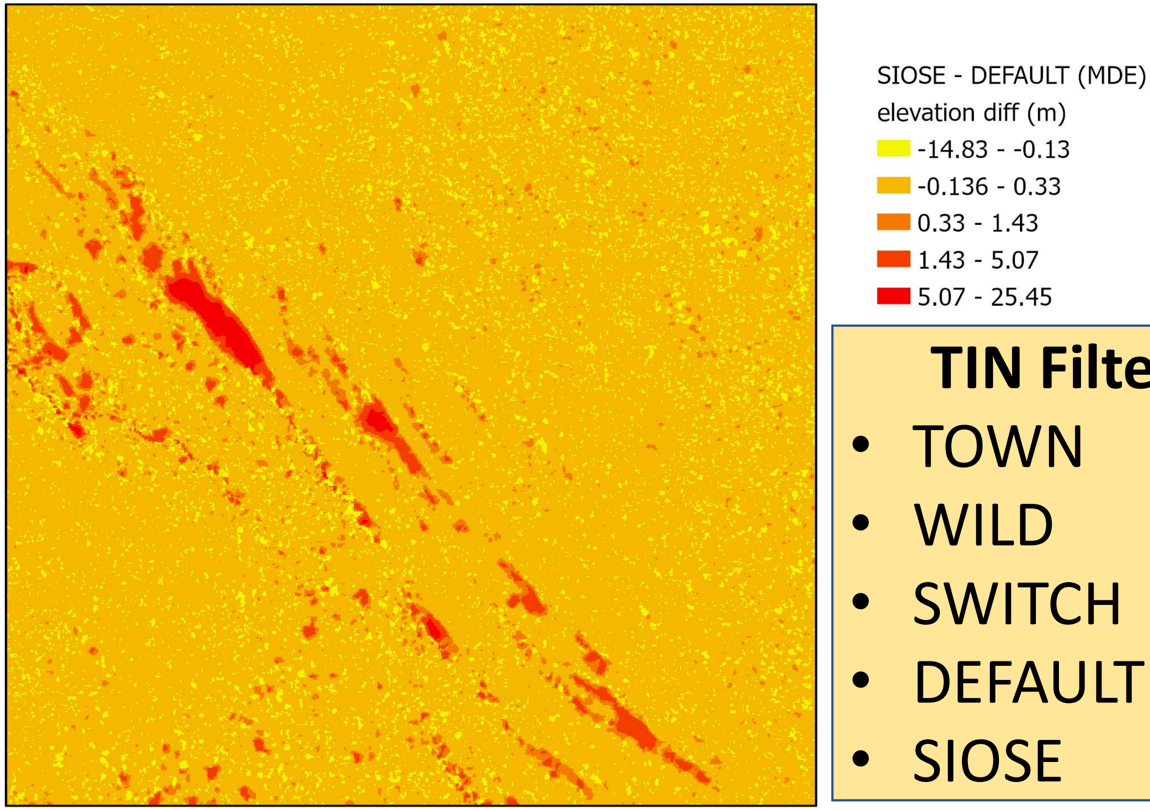
- Height (min, max, mean, sd)
- Lenght
- Diameter
- Area
- Horinzontality
- Sphericity…



RESULTS

1. SENSITIVITY ANALYSIS OF THE DIFFERENT PROGRESSIVE DENSIFICATION FILTERS

DEFAULT – SIOSE DEMs

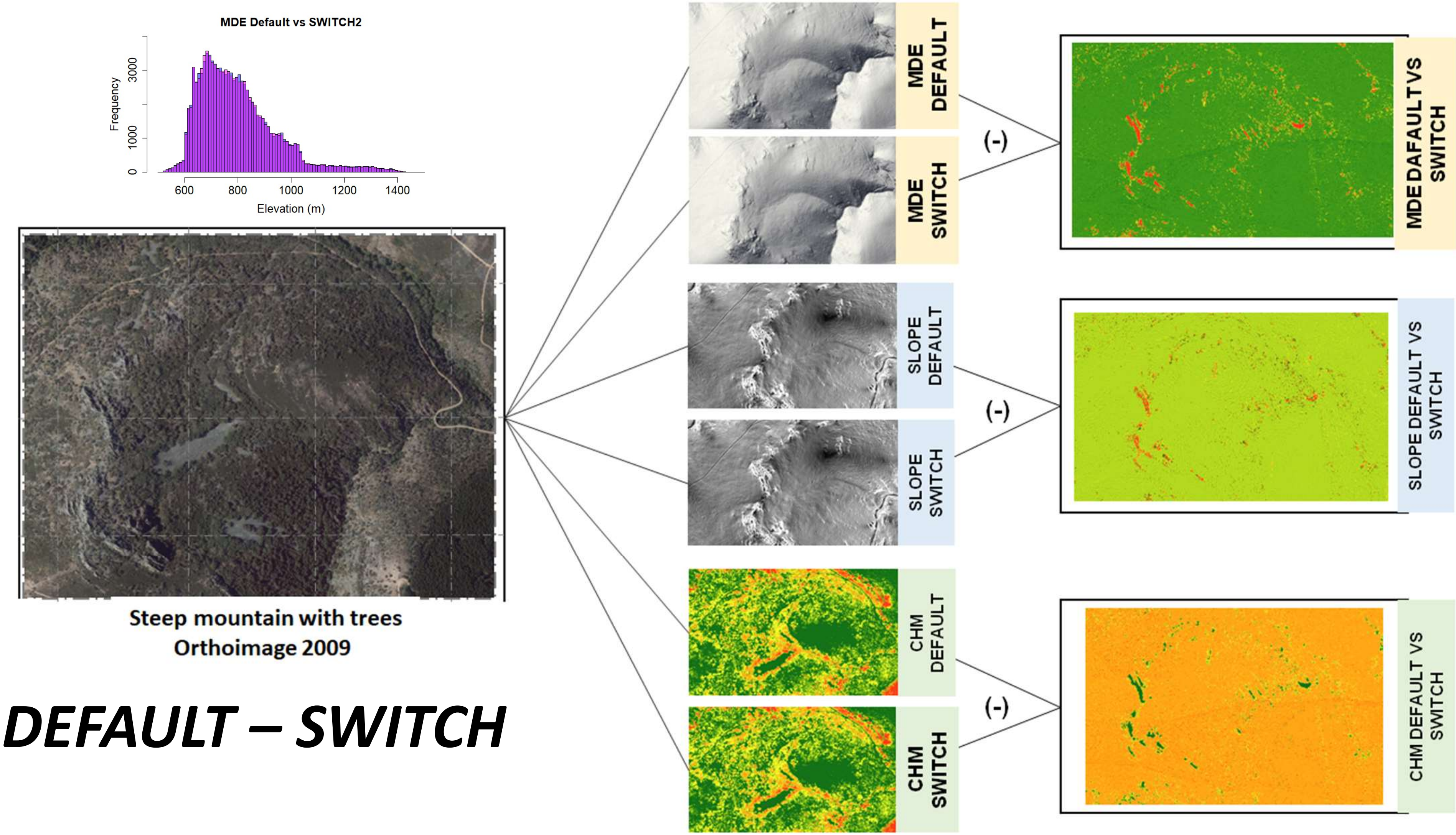


TIN Filters:

- TOWN
- WILD
- SWITCH
- DEFAULT
- SIOSE

RESULTS

1. SENSITIVITY ANALYSIS OF THE DIFFERENT PROGRESSIVE DENSIFICATION FILTERS



RESULTS

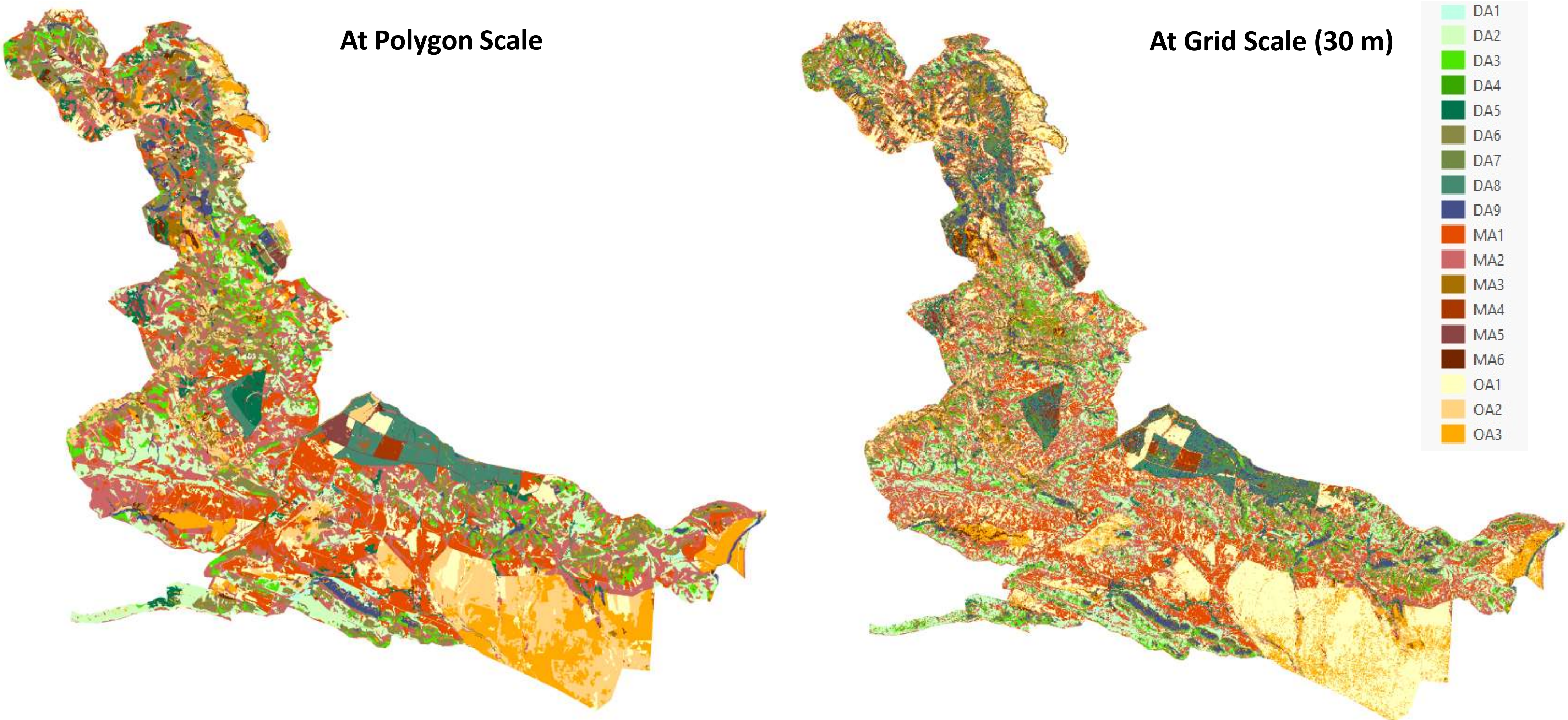
2. FUELS STRUCTURE CHARACTERIZATION (LIDAR DATA)

Fractional cover	Understory height	Treeless /Open forests (FCC trees < 25 %)	Transitional forests (FCC trees < 50 %)	Dense forests (FCC trees ≥ 50 %)
LOW LOAD (FCCtot < 25 %)	small: < 1m medium: 1-2m tall: 2-4 m	OA1 OA2 OA2		
MODERATE LOAD (FCCtot ≥ 25 and < 50 %)	small: < 1m medium: 1-2m tall: 2-4 m	MA1 MA2 MA3	MA4 MA5 MA6	
HIGH LOAD (FCCtot ≥ 50 %)	small: < 1m medium: 1-2m tall: 2-4 m	DA1 DA2 DA3	DA4 DA5 DA6	DA7 DA8 DA9

OA: Open areas (low fuel load)
MA: Medium areas (moderate fuel load)
DA: Dense areas (high fuel load)

RESULTS

FUELS STRUCTURE CHARACTERIZATION (LIDAR)

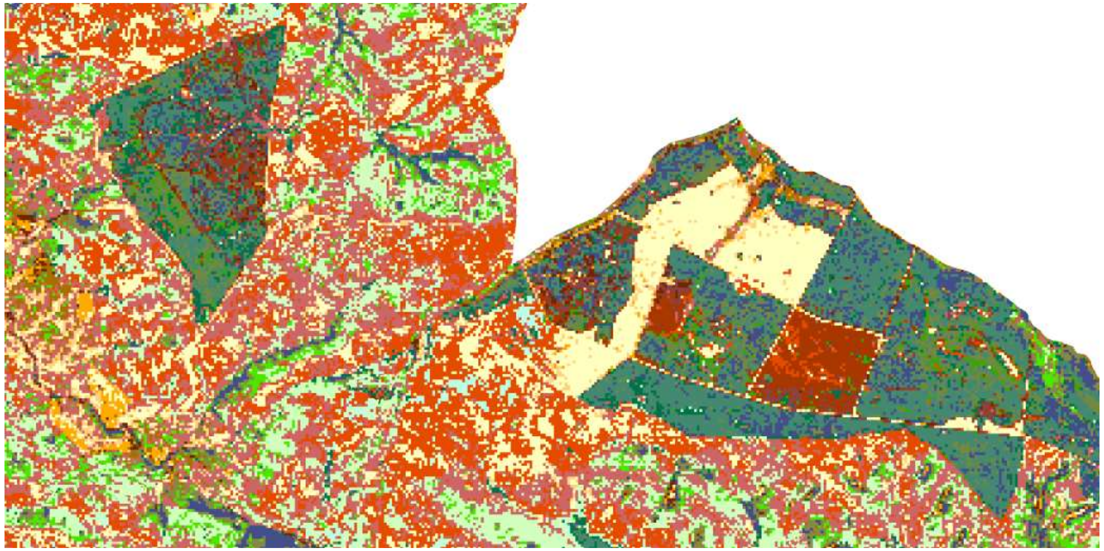


RESULTS

FUELS STRUCTURE CHARACTERIZATION (LIDAR)

At Polygon Scale

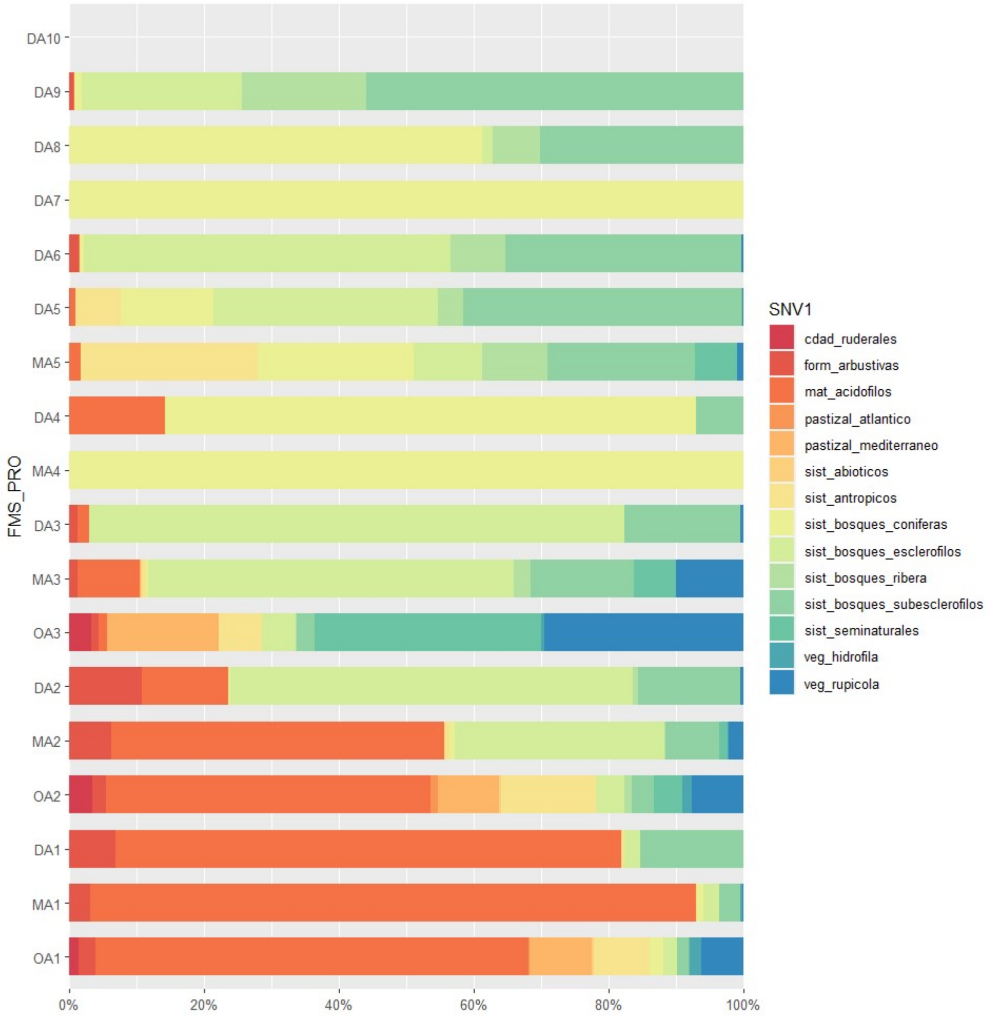
At Grid Scale (30 m)



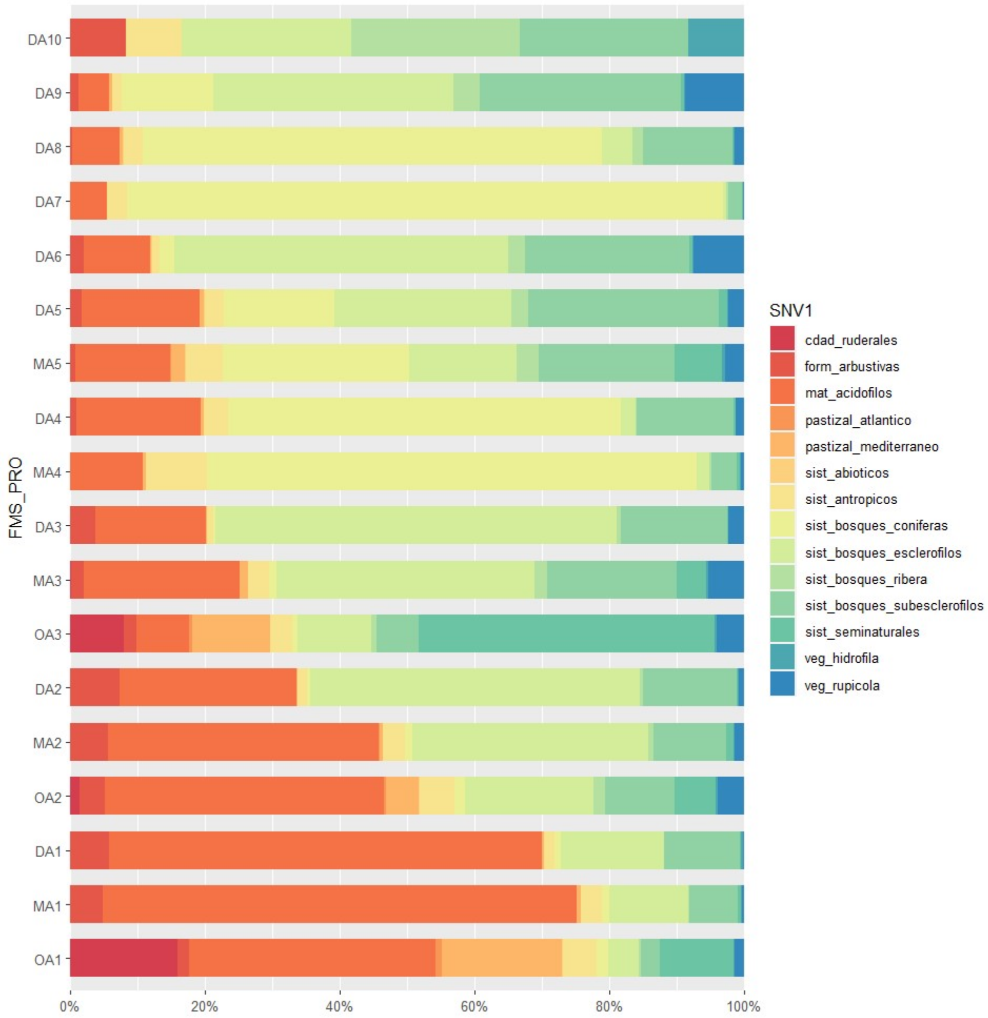
RESULTS

FUEL MODELS OF MAIN VEGETATION TYPES

At Polygon Scale



At Grid Scale (30 m)



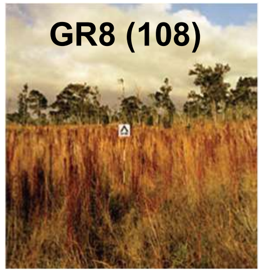
RESULTS

GRASSLANDS (GR) (Scott and Burgan)	Understory height	Treeless /Open forests (FCC trees < 25 %)
VERY LOW LOAD	small: < 1m	GR1-D
LOW LOAD (FCCtot < 25 %)	small: < 1m medium: 1-2m tall: 2-4 m	(GR2-D/GR3-H) - GR5-H
MODERATE LOAD (FCCtot ≥ 25 and < 50 %)	small: < 1m medium: 1-2m tall: 2-4 m	(GR4-D/GR6-H)
HIGH LOAD (FCCtot ≥ 50 %)	small: < 1m medium: 1-2m tall: 2-4 m	(GR7-D/GR8-H) GR9-H

LIDAR + VEGETATION MAP + HUMIDITY CONDITIONS

D-H: Dry - Humid

GR1-D	OA
(GR2-D/GR3-H)	OA1-GRASS
GR5-H	OA1-GRASS
(GR4-D/GR6-H)	MA1-GRASS
(GR7-D/GR8-H)	DA1-GRASS
GR9-H	DA2-GRASS
	DA3-GRASS



RESULTS

SHRUBS (SH) (Scott and Burgan)	Understory height	Treeless /Open forests (FCC trees < 25 %)
VERY LOW LOAD	small: < 1m	
LOW LOAD (FCCtot < 25 %)	small: < 1m	(SH1-D/SH6-H)
	medium: 1-2m tall: 2-4 m	SH4-H
MODERATE LOAD (FCCtot ≥ 25 and < 50 %)	small: < 1m	SH2-D
	medium: 1-2m tall: 2-4 m	SH3-H
HIGH LOAD (FCCtot ≥ 50 %)	small: < 1m	SH8-H
	medium: 1-2m	SH5-D
	tall: 2-4 m	(SH7-D/SH9-H)

LIDAR + VEGETATION MAP + HUMIDITY CONDITIONS

(SH1-D/SH6-H)	OA1-SHRUBS
SH4-H	OA2-SHRUBS
	OA3-SHRUBS
SH2-D	MA1-SHRUBS
SH3-H	MA2-SHRUBS
	MA3-SHRUBS
SH8-H	DA1-SHRUBS
SH5-D	DA2-SHRUBS
(SH7-D/SH9-H)	DA3-SHRUBS

D-H: Dry - Humid

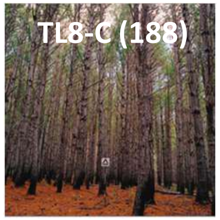
RESULTS

TIMBER UNDERSTORY (Scott and Burgan)	Understory height	Transitional forests (FCC trees < 50 %)	Dense forests (FCC trees ≥ 50 %)
VERY LOW LOAD			
LOW LOAD (FCCtot < 25 %)			
MODERATE LOAD (FCCtot ≥ 25 and < 50 %)	litter: < 1m grass-shrub: 1-2m shrub: 2-4 m	(TU1-D/TU3-H) TU2	
HIGH LOAD (FCCtot ≥ 50 %)	litter: < 1m grass-shrub: 1-2m shrub: 2-4 m	TU5	(TL1 -C TL8-C) /TL2-B (TL3-C/TL6-B) (TL5-C/TL9-B)

LIDAR + VEGETATION MAP + HUMIDITY CONDITIONS

(TU1-D/TU3-H)	MA5-GS
TU2	MA6-GS
TU5	DA6-S
(TL1 -C TL8-C) /TL2-B	DA7-CB
(TL3-C/TL6-B)	DA8-CB
(TL5-C/TL9-B)	DA9-CB

C-B: Conifer – Broadleaved forests   D-H: Dry - Humid



DISCUSSION-CONCLUSIONS

The **TIN filter** based on **default switches** for separating “***ground –non ground***” points was more accurate than the other TIN switches.

The **Silva´s and Dalponte´s segmentation methods** to identify the **trees crowns** were best than the watershed one.

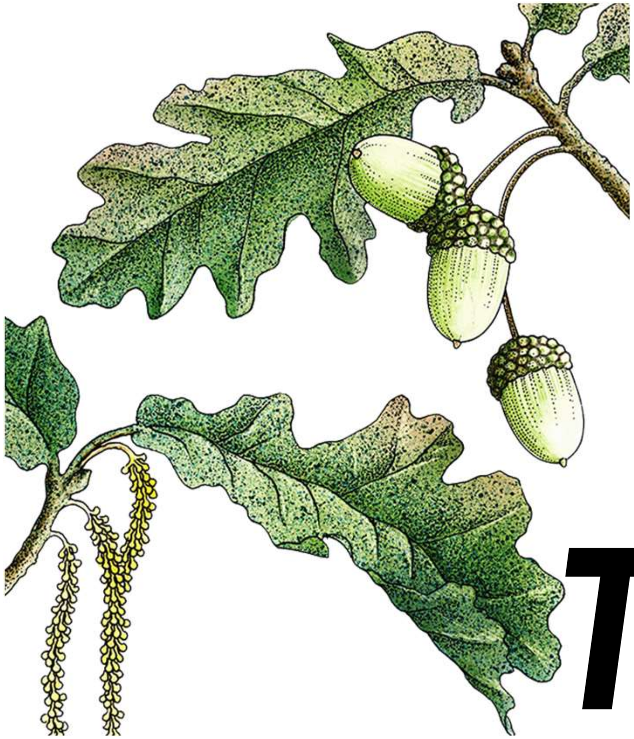
Our**“own” fuel models (FMs)** were based on **vegetation structure** (Lidar data): the percentage of vegetation cover (fuel load), the height of the understory, and distinguising between open-transitional-dense Forests.

The link between our own FMs and standard FMs as the **Scott and Burgan**´s ones requires to cross our FMs with Vegetation and Forests maps to allow identifying **dominant species** and then, to be able for differentiating between ***Grass-Shrubs*** and between ***Conifers-Broadleaved Forests.***

Future work:

To get other auxiliary information as **proxy of the fuel moisture** such as the wetness index of the Tasseled Cap Transformation from Landsat, the LAI/FPAR from MODIS images, topographic wetness index...

To characterize **vegetation vulnerability** based on the **flammability** conditions and the capacity to cope with fire of the different **plant funtional traits.**



THANK YOU