

## II Seminario: Las nuevas tecnologías aplicadas al conocimiento de los ecosistemas



### LA TELEDETECCIÓN COMO HERRAMIENTA PARA LA GESTIÓN FORESTAL

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### 1) Caracterización estructural

- cartografía de variables estructurales a partir de ALS (e.g. CH, LAI, FCC, AGB)
- actualización con sensores activos/pasivos
- actualización con segmentación temporal

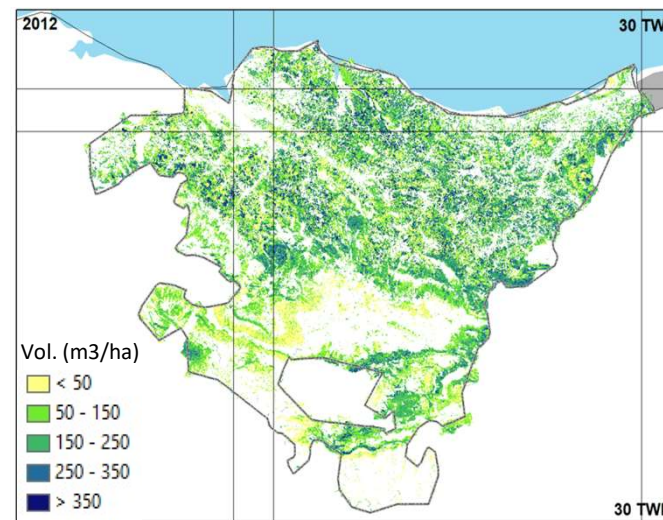
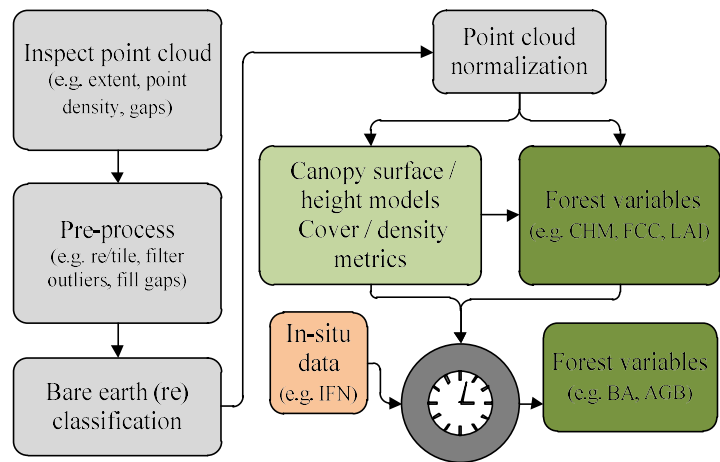
### 2) Perturbaciones forestales: SAFoD

- perturbaciones históricas (1984-2022)

### 3) Propiedades de combustibles

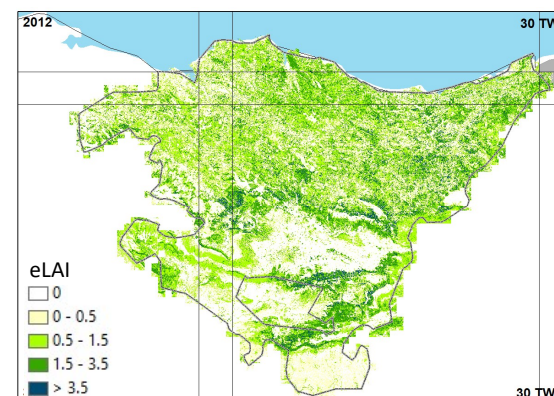
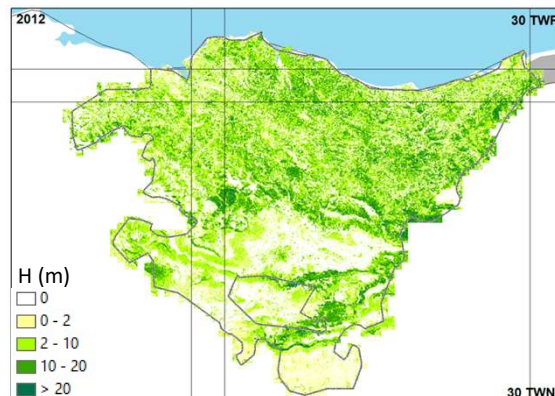
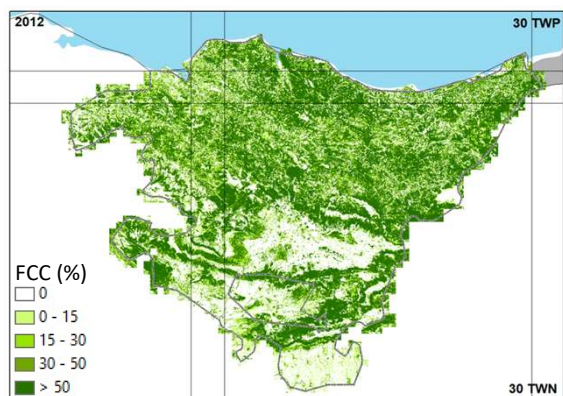
- humedad del combustible vivo (LFMC)

# 1) Caracterización estructural

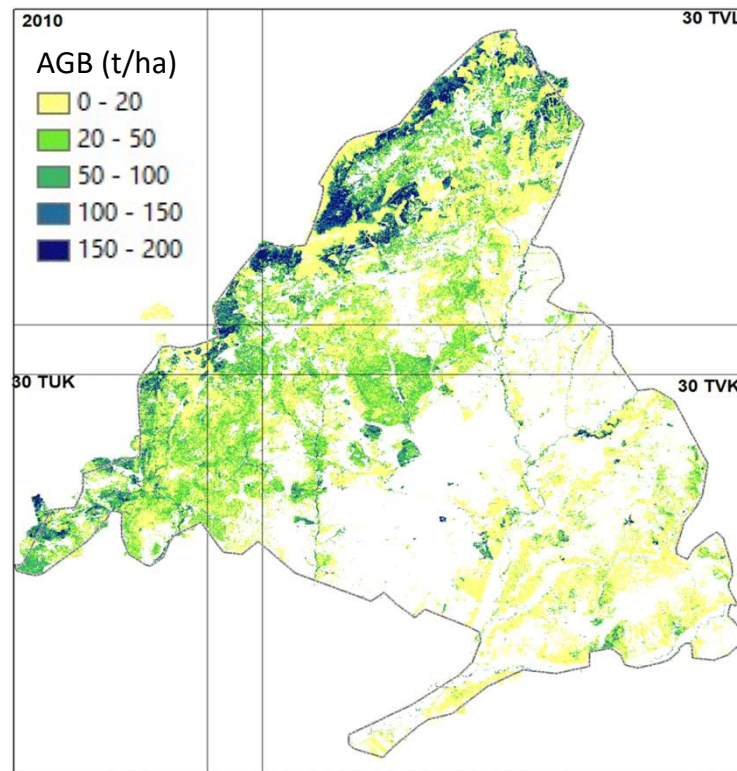
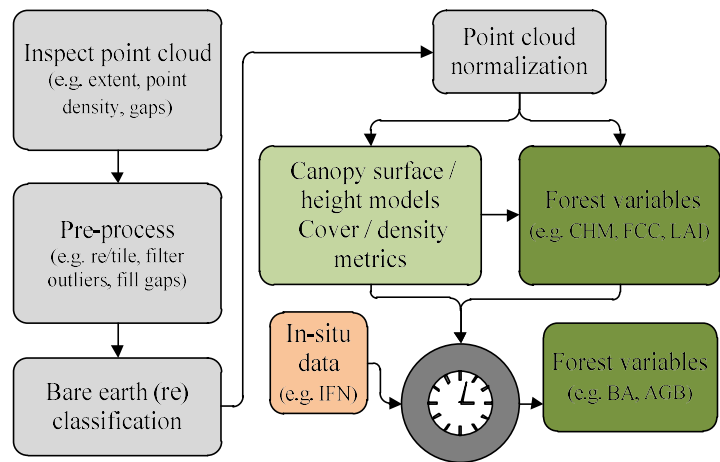


RMSE = 74.3 // 106.5 m<sup>3</sup>/ha

$r \sim 0.8$

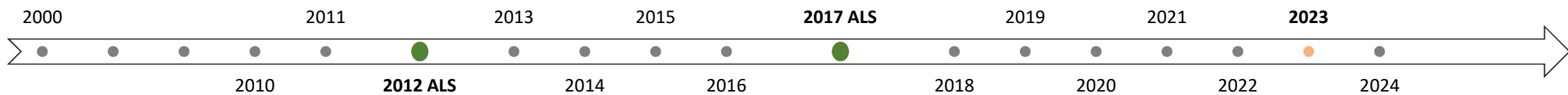


# 1) Caracterización estructural

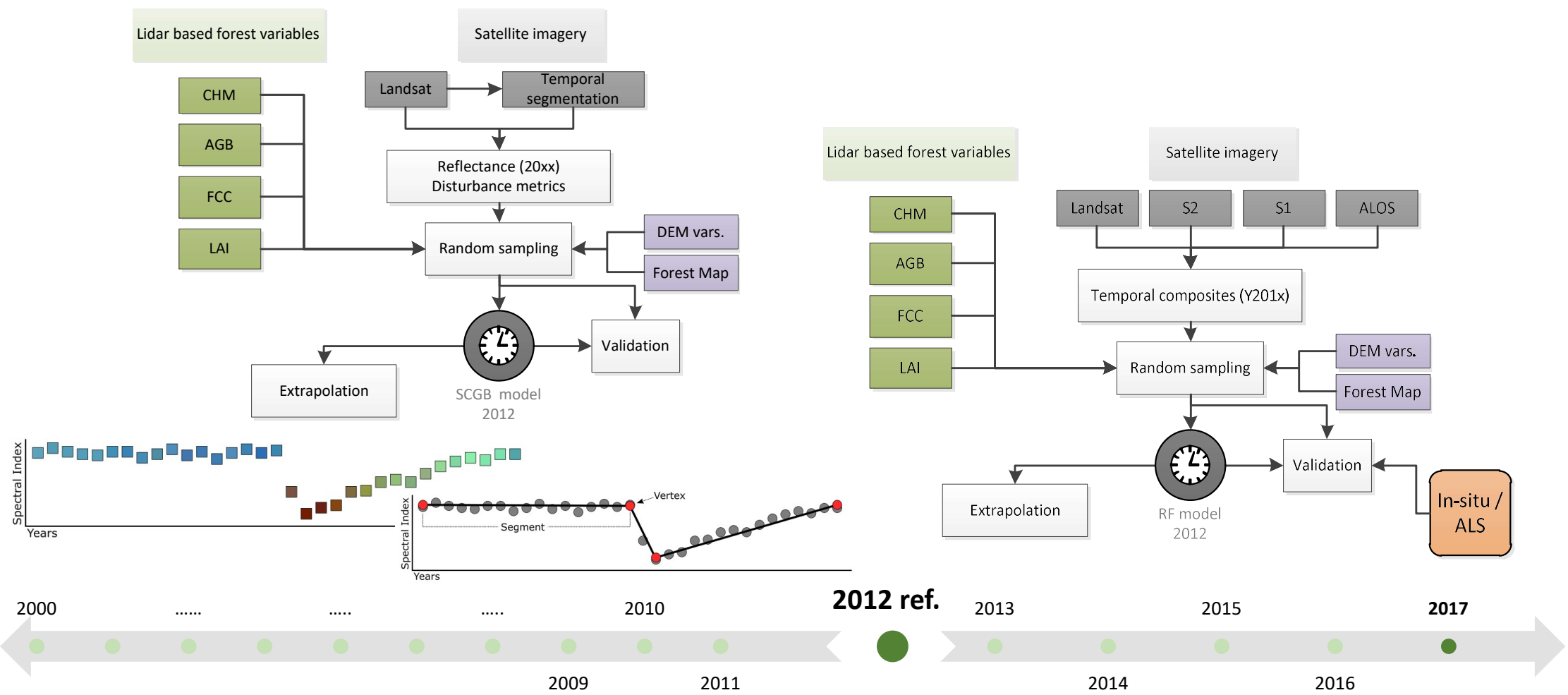


RMSE= 28.6 // 31.5 t/ha

$r \sim 0.88$



# 1) Caracterización estructural



# 1) Caracterización estructural

RF & L8/9, S2, S1, PALSAR (2010 → .....)

| Landsat  |      |       |       |                           |
|----------|------|-------|-------|---------------------------|
| Variable | R2   | RMSE  | MAE   | CLASE                     |
| FCC      | 0.76 | 15.32 | 11.01 | Global                    |
| CHM      | 0.77 | 1.82  | 1.15  | Global                    |
| FCC      | 0.33 | 10.88 | 6.60  | Matorral                  |
| CHM      | 0.34 | 0.95  | 0.51  | Matorral                  |
| FCC      | 0.23 | 12.71 | 8.13  | Sin vegetación            |
| CHM      | 0.24 | 1.07  | 0.64  | Sin vegetación            |
| FCC      | 0.71 | 17.17 | 13.14 | Veg. Arbórea de coníferas |
| CHM      | 0.69 | 2.76  | 2.05  | Veg. Arbórea de coníferas |
| FCC      | 0.64 | 16.60 | 12.65 | Veg. Arbóres de frondosas |
| CHM      | 0.67 | 1.61  | 1.09  | Veg. Arbóres de frondosas |
| FCC      | 0.11 | 15.65 | 10.20 | Vegetación herbácea       |
| CHM      | 0.12 | 1.73  | 0.92  | Vegetación herbácea       |

| Sentinel-2 |      |       |       |        |
|------------|------|-------|-------|--------|
| Variable   | R2   | RMSE  | MAE   | CLASE  |
| FCC        | 0.79 | 14.32 | 10.29 | Global |
| CHM        | 0.79 | 1.73  | 1.10  | Global |

| Landsat & Sentinel-2 & PALSAR* |      |       |       |                |
|--------------------------------|------|-------|-------|----------------|
| Variable                       | R2   | RMSE  | MAE   | CLASE          |
| AGB                            | 0.77 | 28.79 | 21.27 | Global         |
| AGB                            | 0.65 | 25.10 | 18.75 | Frondosas      |
| AGB                            | 0.73 | 36.68 | 28.72 | Coníferas      |
| AGB                            | 0.37 | 22.63 | 15.54 | Matorral       |
| AGB                            | 0.19 | 25.54 | 19.77 | Sin vegetación |
| AGB                            | 0.14 | 32.67 | 24.48 | Herbáceas      |

| Landsat & Sentinel-2                            |      |       |       |        |
|-------------------------------------------------|------|-------|-------|--------|
| Variable                                        | R2   | RMSE  | MAE   | CLASE  |
| FCC                                             | 0.80 | 14.12 | 10.15 | Global |
| CHM                                             | 0.81 | 1.69  | 1.07  | Global |
| Sentinel-2 & Sentinel-1 ( $\sigma^\circ$ + Coh) |      |       |       |        |
| Variable                                        | R2   | RMSE  | MAE   | CLASE  |
| FCC                                             | 0.79 | 14.28 | 10.25 | Global |
| CHM                                             | 0.80 | 1.72  | 1.09  | Global |

| Sentinel-2 & Sentinel-1 ( $\sigma^\circ$ ) |      |       |       |        |
|--------------------------------------------|------|-------|-------|--------|
| Variable                                   | R2   | RMSE  | MAE   | CLASE  |
| FCC                                        | 0.73 | 15.60 | 11.96 | Global |
| CHM                                        | 0.77 | 1.94  | 1.32  | Global |

| Sentinel-2 & Sentinel-1 & PALSAR* |      |       |       |        |
|-----------------------------------|------|-------|-------|--------|
| Variable                          | R2   | RMSE  | MAE   | CLASE  |
| FCC                               | 0.74 | 15.45 | 11.85 | Global |
| CHM                               | 0.78 | 1.90  | 1.29  | Global |

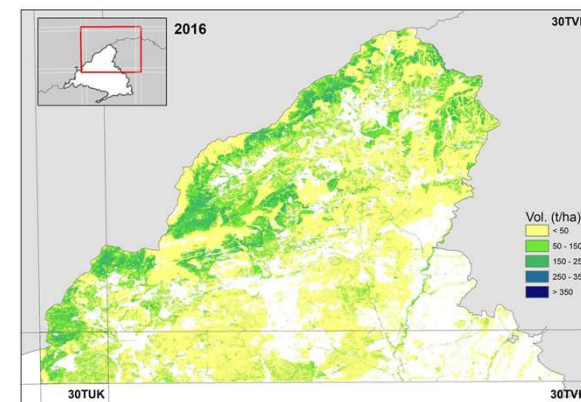
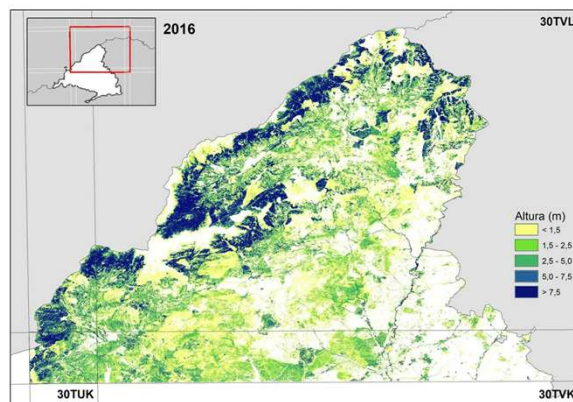
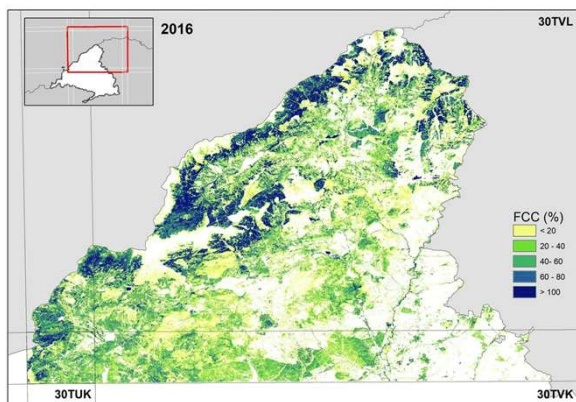
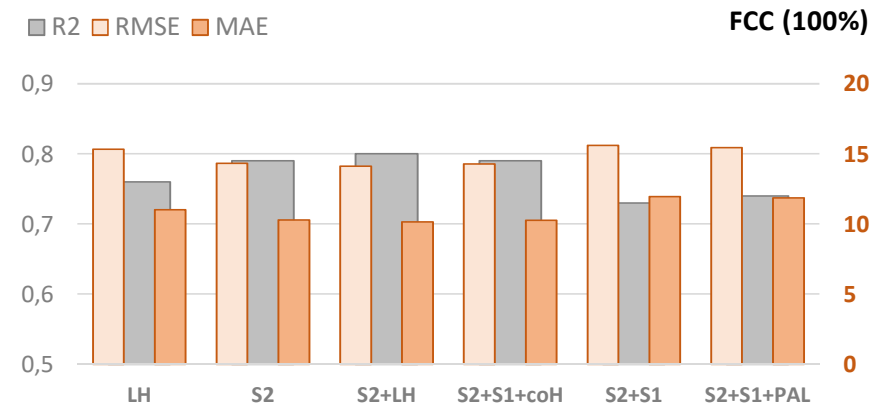
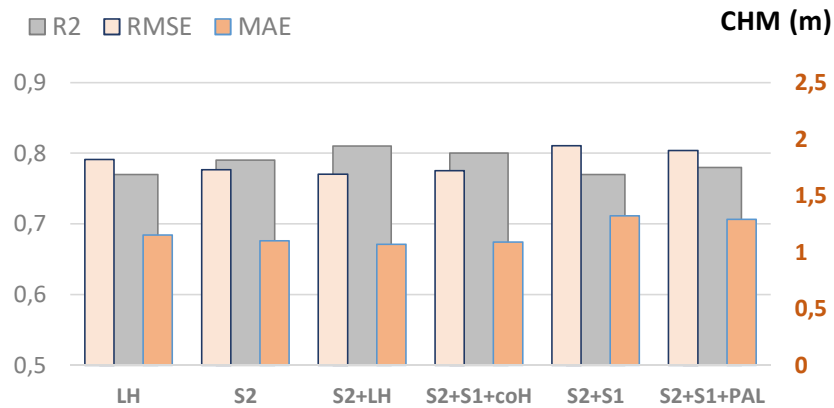
| Sentinel-2 & Sentinel-1 ( $\sigma^\circ$ ) |      |       |       |                |
|--------------------------------------------|------|-------|-------|----------------|
| Variable                                   | R2   | RMSE  | MAE   | CLASE          |
| AGB                                        | 0.76 | 29.36 | 21.71 | Global         |
| AGB                                        | 0.72 | 37.10 | 29.11 | Coníferas      |
| AGB                                        | 0.65 | 25.37 | 18.94 | Frondosas      |
| AGB                                        | 0.35 | 24.57 | 16.82 | Matorral       |
| AGB                                        | 0.15 | 38.01 | 27.26 | Herbácea       |
| AGB                                        | 0.21 | 28.97 | 21.32 | Sin vegetación |

| Sentinel-2 & Sentinel-1 ( $\sigma^\circ$ ) |            |       |
|--------------------------------------------|------------|-------|
| Variable                                   | Importance | Model |
| B11                                        | 3.24       | FCC   |
| B12                                        | 3.46       | FCC   |
| B2                                         | 2.98       | FCC   |
| B3                                         | 4.95       | FCC   |
| B4                                         | 6.95       | FCC   |
| B5                                         | 7.83       | FCC   |
| B6                                         | 6.46       | FCC   |
| B7                                         | 4.64       | FCC   |
| B8                                         | 3.91       | FCC   |
| evi                                        | 3.49       | FCC   |
| ndvi                                       | 4.53       | FCC   |
| ndwi                                       | 5.14       | FCC   |
| vh                                         | 7.71       | FCC   |
| vv                                         | 9.40       | FCC   |
| class                                      | 25.29      | FCC   |



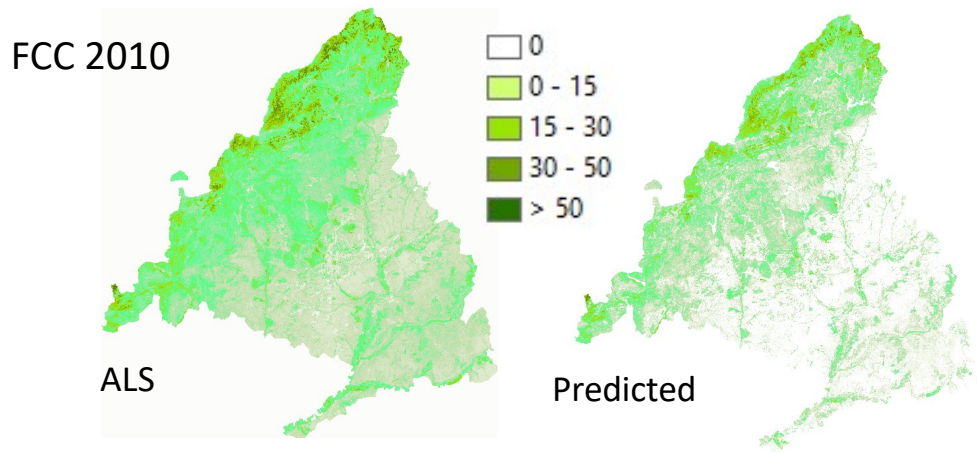
# 1) Caracterización estructural

RF & L8/9, S2, S1, PALSAR (2010 → .....)

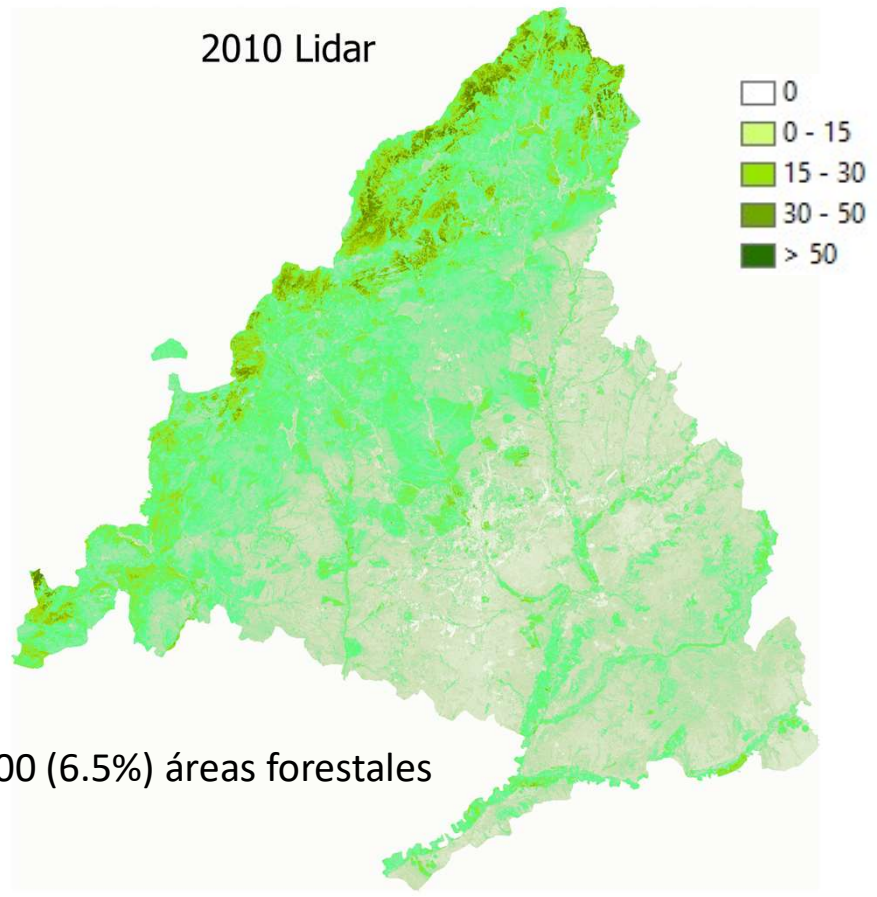


# 1) Caracterización estructural

SCGB & Landsat segmentation (1984 → 2010)



DL subestima el los valores FCC del ALS



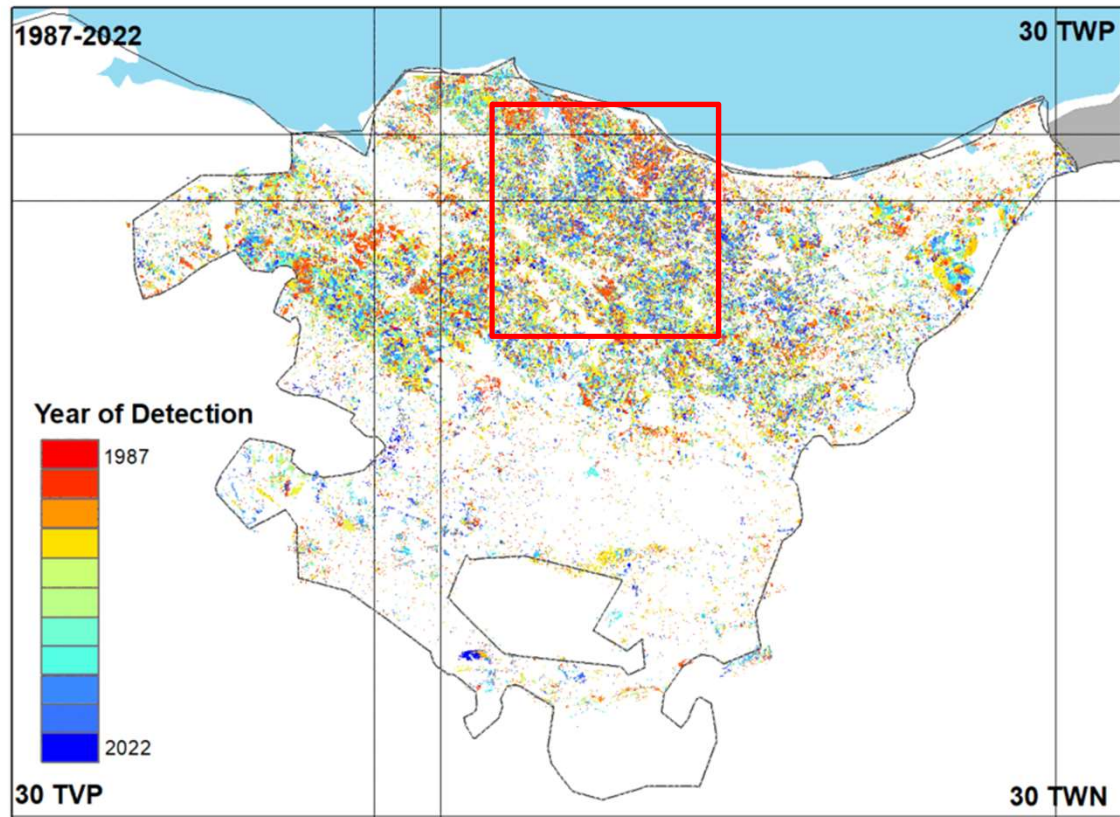
FCC 2009 > FCC 2000 (6.5%) áreas forestales

SCGB: scaled conjugated gradient backpropagation)

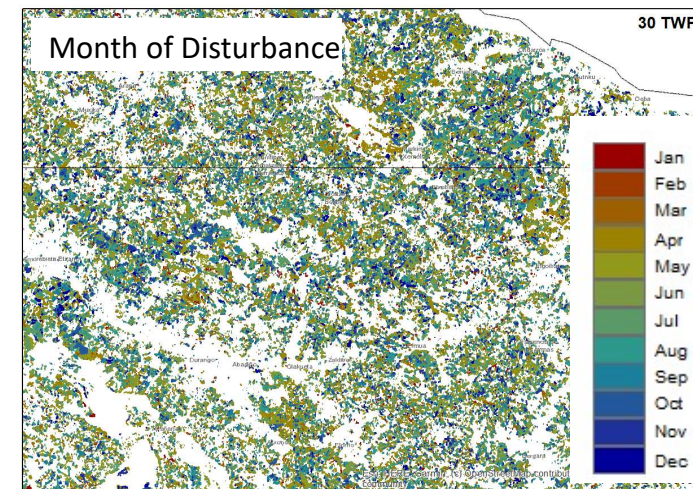
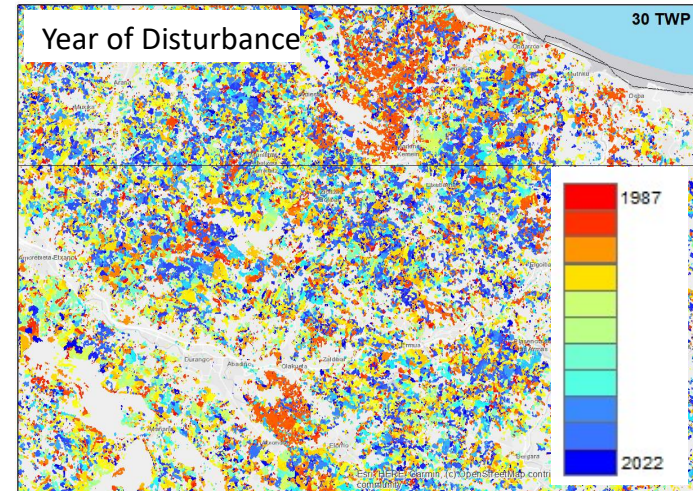
[https://rpubs.com/tma\\_xxl/ForesStruct\\_Dist](https://rpubs.com/tma_xxl/ForesStruct_Dist)



## 2) Cartografía de las perturbaciones: SAFoD

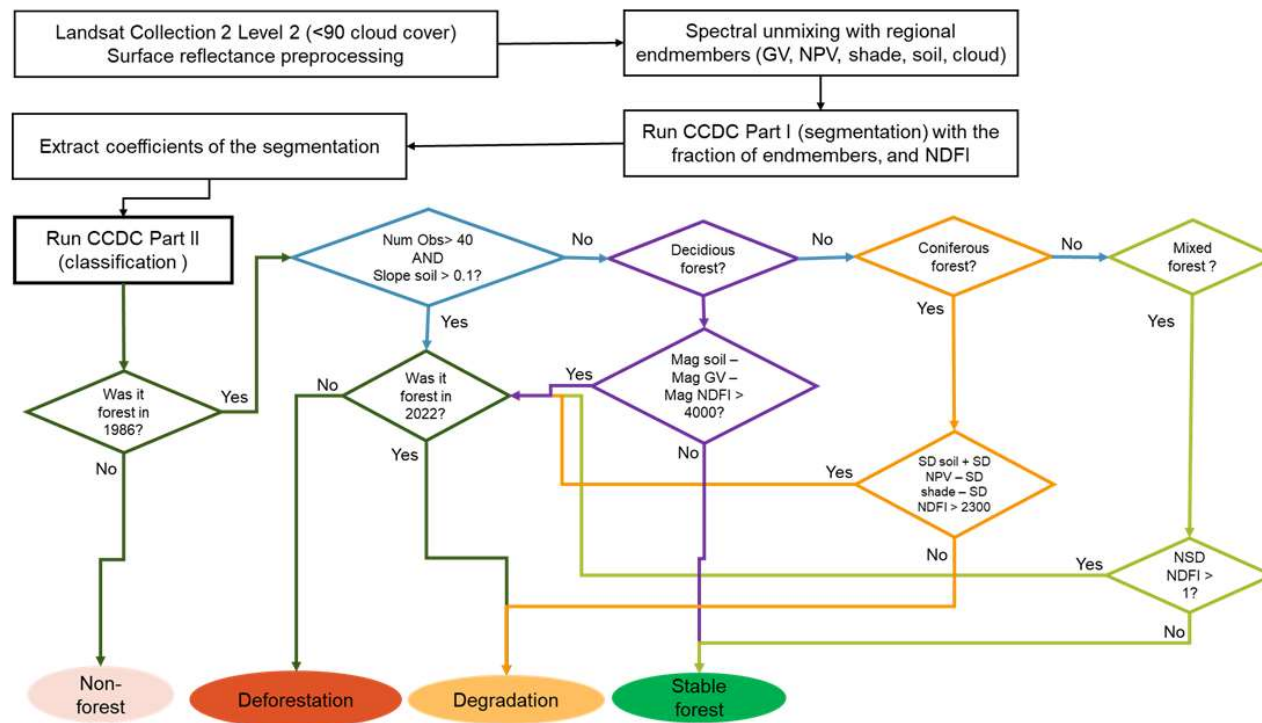


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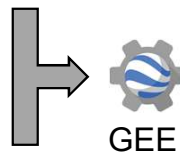


## 2) Cartografía de las perturbaciones: SAFoD

Continuous change  
detection and classification -  
Spectral Mixture Analysis  
**CCDC- SMA**



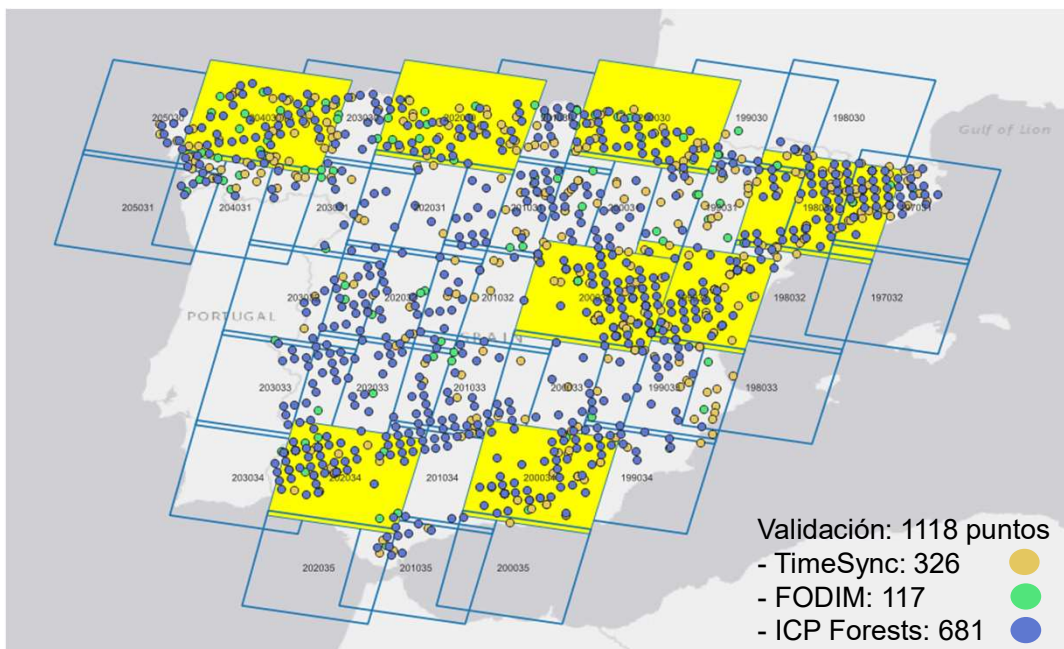
CCDC - Zhu and Woodcock, 2014.  
SMA - Souza et al., 2005; Souza et al., 2013  
CODED - Bullock et al 2020



Chen et al. 2021

## 2) Cartografía de las perturbaciones: SAFoD

### CCDC-SMA parameter tuning / validation



#### Próximamente

1. Ajustes finales y mejora del post-procesamiento
2. Aplicar a toda España + validación final + comparación
3. Clasificar agentes (incendio, cortas, plagas,...).
4. Analizar tendencias y patrones a nivel nacional y regional

### Ajuste de parámetros

#### Segmentation:

1. minObservations : 4
2. chiSquareProbability: .95
3. minNumOfYearsScaler: 1
4. breakpointBands: *WETNESS, NDFI, GV, NPV, SOIL, SHADE*
5. Lambda: 10
6. maxIterations : 10000

#### Spectral mixture analysis

1. ab\_threshold: .90
2. gr\_threshold: 0.5
3. ch\_prob: 0.95

### Validación preliminar

| Bioma                | OA (%) | CI 95 (%) | CI 95 (%) | n   | Validation databases        | ICP def. limit |
|----------------------|--------|-----------|-----------|-----|-----------------------------|----------------|
| Atlántico/<br>Alpino | 88.3   | 83.2      | 92.2      | 212 | TimeSync, FoDiM, ICP Forest | >80%           |
|                      | 84.5   | 78.9      | 89.1      | 212 | TimeSync, FoDiM, ICP Forest | >80%           |
|                      | 80.4   | 71.6      | 87.4      | 106 | ICP Forest                  | >60%           |
|                      | 96.3   | 90.7      | 98.9      | 106 | TimeSync, FoDiM             |                |
| Mediterráneo         | 86.1   | 82.0      | 89.5      | 351 | TimeSync, FoDiM, ICP Forest | >80%           |
|                      | 83.8   | 79.5      | 87.5      | 351 | TimeSync, FoDiM, ICP Forest | >60%           |
|                      | 79.2   | 73.4      | 84.1      | 234 | ICP Forest                  | >80%           |
|                      | 100    | 96.9      | 100       | 117 | TimeSync, FoDiM             |                |

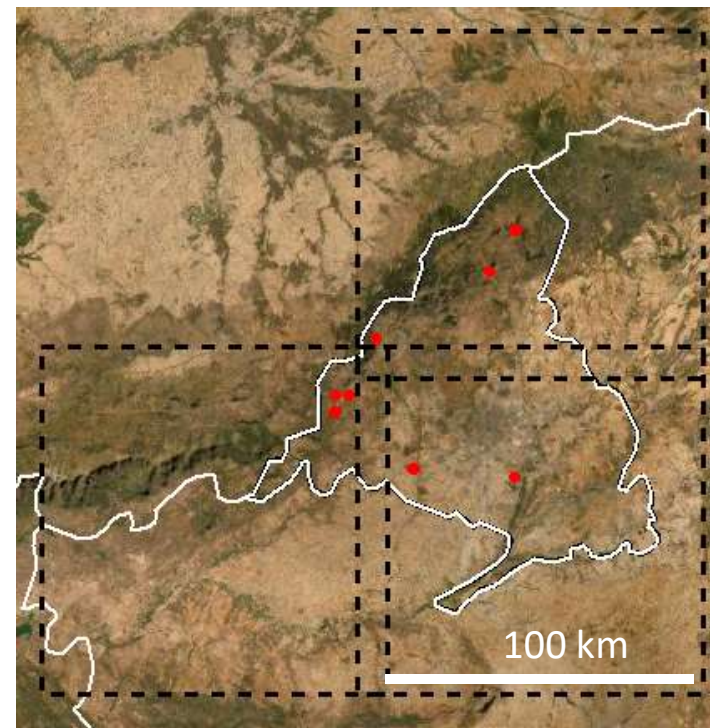


### 3) Propiedades de combustibles

*Humedad del combustible vivo (LFMC)*  $\frac{\text{Fresh weight} - \text{Dry weight}}{\text{Dry weight}}$  ( $\text{kg kg}^{-1}$ )

#### CAM

16 parcelas (800-2400 m<sup>2</sup>)  
4109 muestras → 2962 usadas  
Periodo: 04/2016 - 12/2021



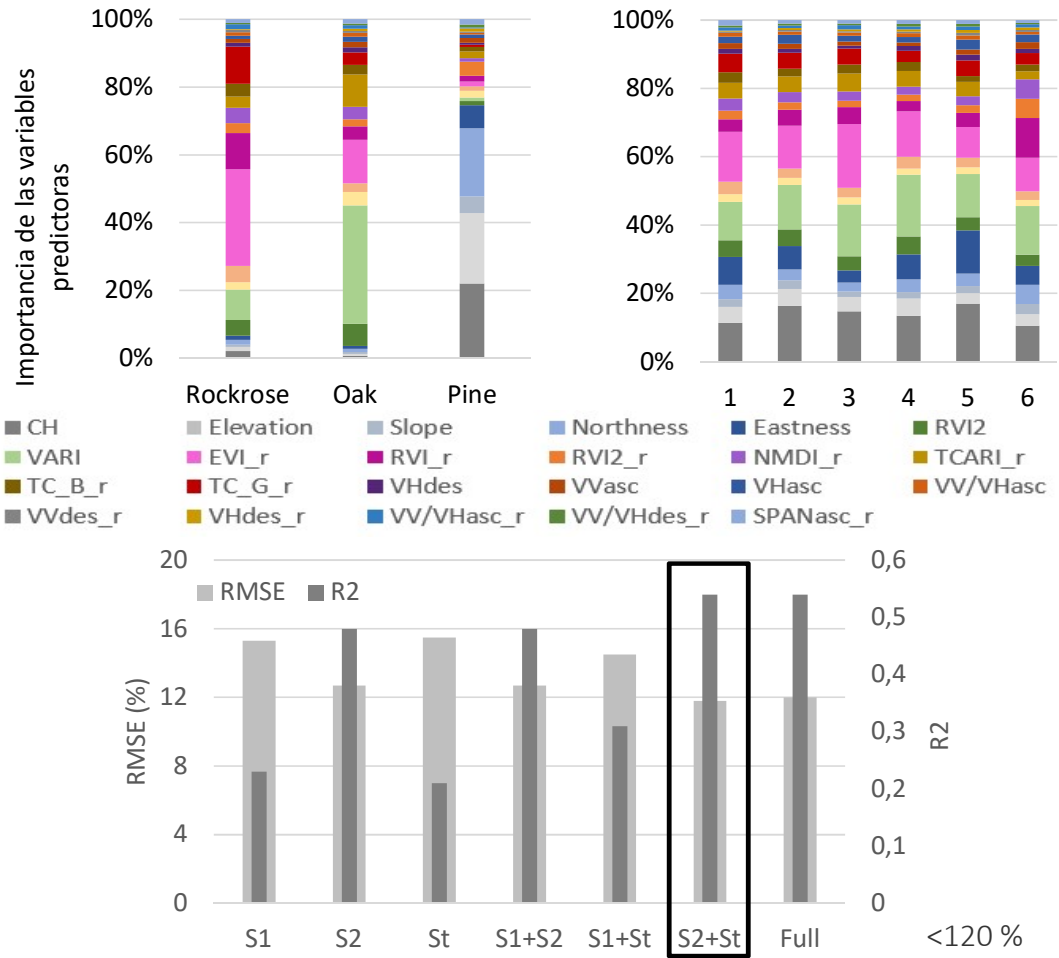
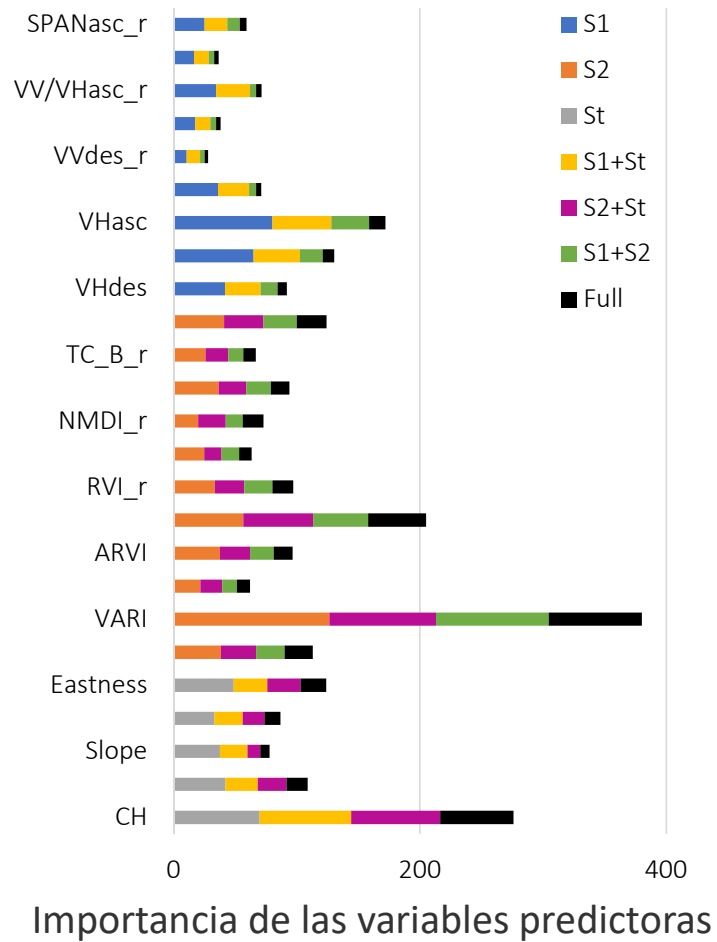
3550 Sentinel-1 A/B: IW (VV, VH) GRD  
613 Sentinel-2 A/B: CC<90% SR, Theia MAJA, 21 SIs

Índices absolutos y relativos (S1,S2, S1+S2)  
 $rSI = (SI - S_{Imin}) / (S_{Imax} - S_{Imin})$

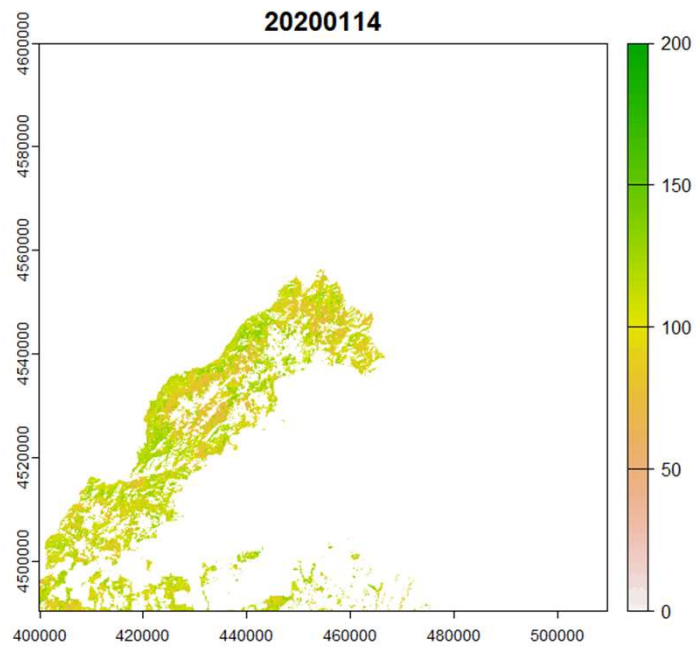
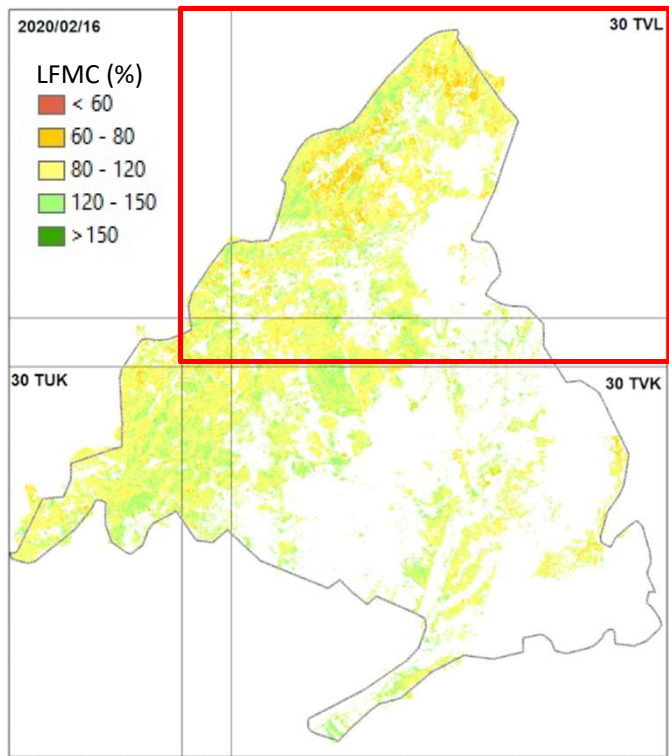
Retraso temporal: ± 3/6 dias

ML (RF) → R<sup>2</sup>, RMSE, MAE, bias

### 3) Propiedades de combustibles



### 3) Propiedades de combustibles



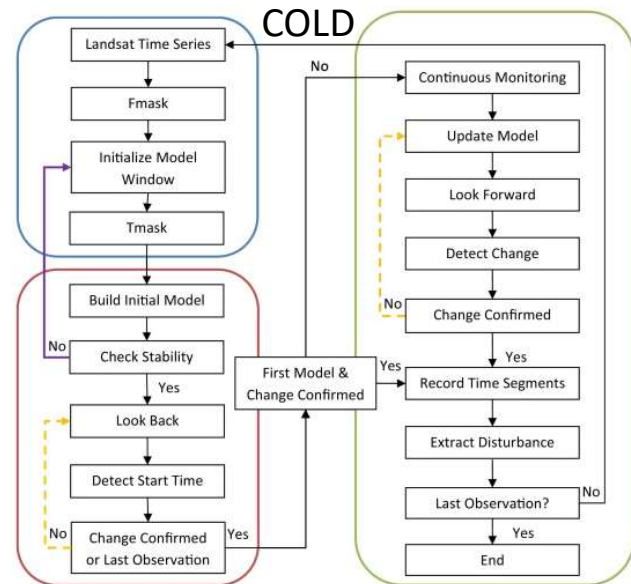
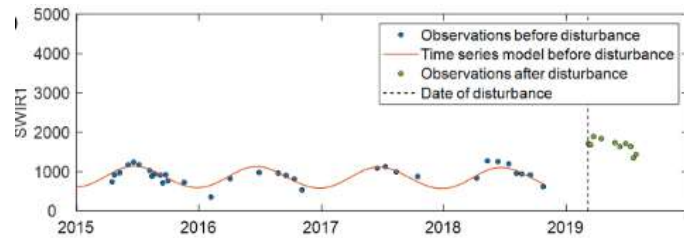
[https://rpubs.com/tma\\_xxl/LFMC2020](https://rpubs.com/tma_xxl/LFMC2020)

- Mejores resultados con óptico (~12% RMSE)
- Óptico & SAR tienen poca sinergia



### 3) Próximamente

Sistema de Monitorización Integrado (SMI)



EOS4FOR

Distribución de la información - web app

# Agradecimientos



MINISTERIO  
DE CIENCIA  
E INNOVACIÓN



Comunidad  
de Madrid



MINISTERIO  
DE TRANSPORTES, MOVILIDAD  
Y AGENDA URBANA



Gracias Elena



Gracias !