
# Detection of old-growth forests through satellite images: a case study in a mediterranean mountain range (Cazorla, southeast Spain)

**Reyes Alejano, Carlos Guerrero, Anabel Calzado, Cristina Pérez Carral, Javier Vázquez-Piqué**

Agroforestry Sciences Department, University of Huelva, Spain

“Aserradores, hacheros, pelaores, ajorraores, pineros, resineros, esencieros, carboneros, leñadores y matuteros, carreteros, arrieros, aladreros, alimañeros, aperadores, cadiceros, cuchareros, seteros, pastores, herbolario, cazadores, pescadores, guardas, carpinteros, mieleros, peluseros, neveros”

Idánez Aguilar, 1995

# Before going to the point….

Old Growth Forests in Spanish and Andalusia Forestry Regulations, Initiatives and Projects

Andalusian OGF

Our Projects on OGF

# Laws and strategic plans about forests

## SPAIN (NATIONAL)

- Law 43/2003 Forests (Montes) It is the basic national regulation on forestry; there is no new draft currently in development.
- Spanish Forest Strategy – Horizon 2050 (approved 2022). Reference document for national forest policy. Considering European Strategy for Biodiversity (2020) that establishes to strictly protect all primary and mature forests in EU, including actions to define, map, monitor and preserve these ecosystems
- Spanish Forest Plan 2022–2032. It implements the Spanish Forest Strategy for the first decade

## ANDALOUSIA (REGIONAL)

- Andalusian Forest Law (1992). A new draft has been under development since 2024.
- Andalusian Forest Plan, approved in 1989 and revised in 2023 to adequate to 2030 Agenda

unesco
Red Española de Reservas de la Biosfera

NATURA 2000

espacios naturales de Andalucía

RED DE PARQUES NACIONALES

| SPANISH FORESTRY STRATEGY- HORIZON 2050 | SPANISH FORESTRY PLAN 2022-2032 |
|---|---|
| **Goal:** To establish a long-term vision for achieving managed, resilient, and multifunctional forests that contribute to social well-being, biodiversity, the green economy, and climate change mitigation<br><br>**Measures:**<br>• Identification, protection, and restoration of forest **ecosystems with high ecological value** (including mature forests).<br>• Creation **of inventories and mapping of forest areas with high conservation value**.<br>• **Integration of old-growth forest conservation into regional and local forest planning instruments.**<br>• Recognizes these forests as critical for climate resilience, biodiversity corridors, and carbon sequestration. | **Goal:** To implement the Spanish Forestry Strategy during its first decade through **289 specific measures**, prioritizing **active and sustainable forest management**, protection against threats and the provision of ecosystem services.<br><br>**Measures:**<br>• Develops a **national inventory of mature and singular forests, including criteria for ecological value, age, structure, and biodiversity.**<br>• **Promotes passive management (non-intervention) in selected old-growth stands**<br>• **Enhances connectivity between mature forest patches to support ecological networks**.<br>• Encourages **monitoring and research on forest aging processes and their role in ecosystem services**. |

| DRAFT OF THE NEW ANDALUSIAN FOREST LAW (2024), law currently in force from 1992 | ANDALUSIAN FOREST PLAN (1989, adequation to Horizon 2030 in 2023) |
|---|---|
| **Goal**: to modernize and adapt the region’s forest legislation to current environmental, social, and economic challenges.<br>**Measures:**<br>• Creation of the “Red MUESTRA” (Network of Exemplary Forests): network of forests managed sustainably, serving as models of best practices in conservation and multifunctional use.<br>• Prioritizes long-term conservation of ecologically valuable forest areas.<br>• Encourages landowners to preserve mature and biodiverse forest stands.<br>• Focuses on enhancing forest structure and ecological functions, especially in areas with old or vulnerable tree populations. | **Goal;** to respond to the evolving ecological, social, and economic challenges facing Andalusia’s forest ecosystems<br>**Measures:**<br>• Adaptive Management of Mediterranean Ecosystems protecting key ecosystem services in forests threatened by climate change, including those with mature or structurally complex vegetation.<br>• Promotes the creation of forest corridors, which benefit old-growth patches and enhance landscape-level resilience.<br>• Strengthens the use of forest inventories and ecological indicators to identify and manage forests of high conservation value. |

# LIFE RedBosques & LIFE RedBosques

LIFE RedBosques (2016–2019)

• Objective: to identify, characterize, and conserve stands of mature forests in Spain.

• Outcomes:

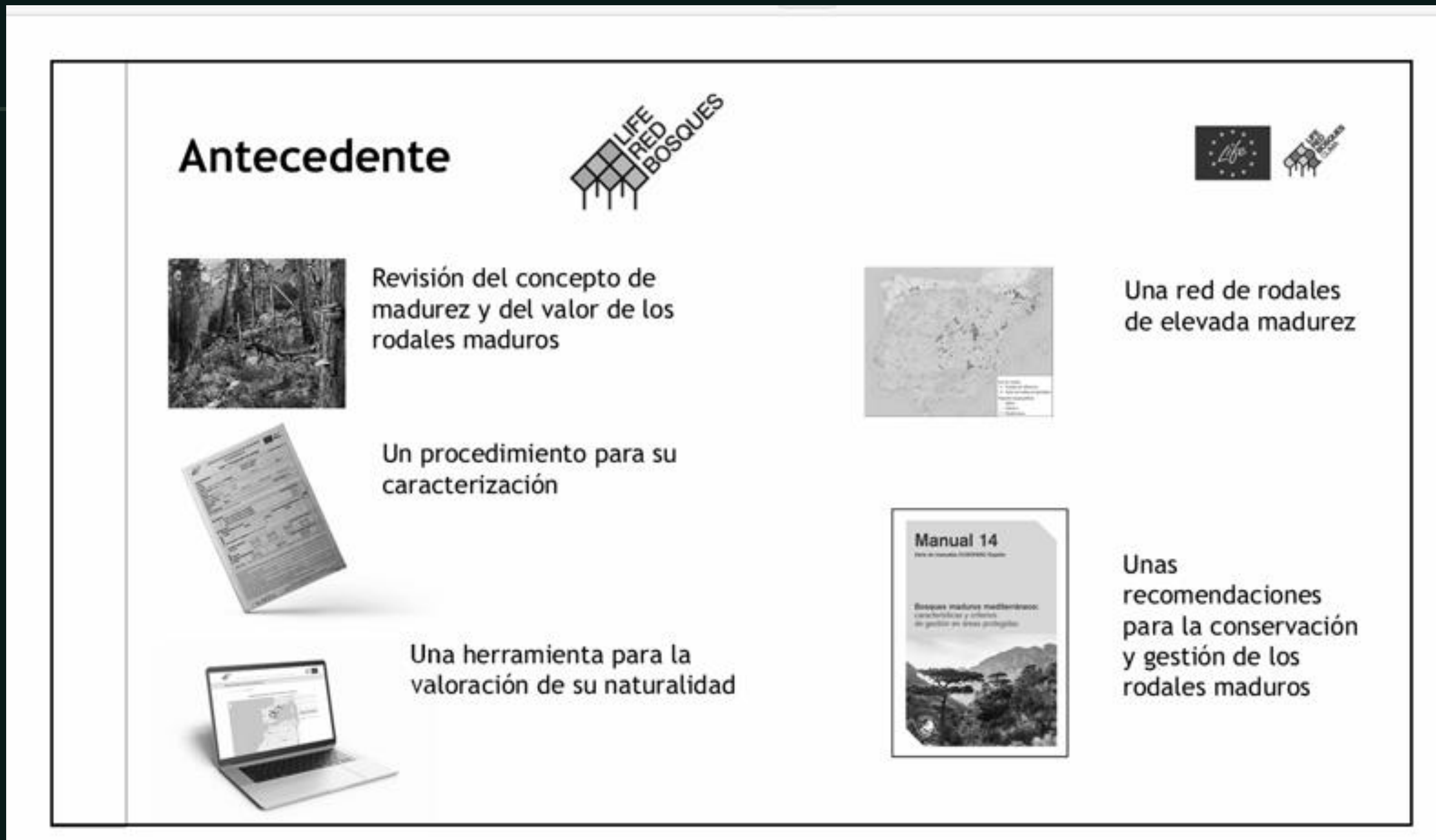
- Identified and characterized mature forest stands.
- Developed protocols to assess forest maturity.
- Created a network of high-maturity forest plots.
- Published management guidelines for maturity conservation.

LIFE RedBosques Clima (2022–2024)

• Focused on the role of mature forests in climate change adaptation and mitigation.

• Has produced technical reports and tools for forest managers.

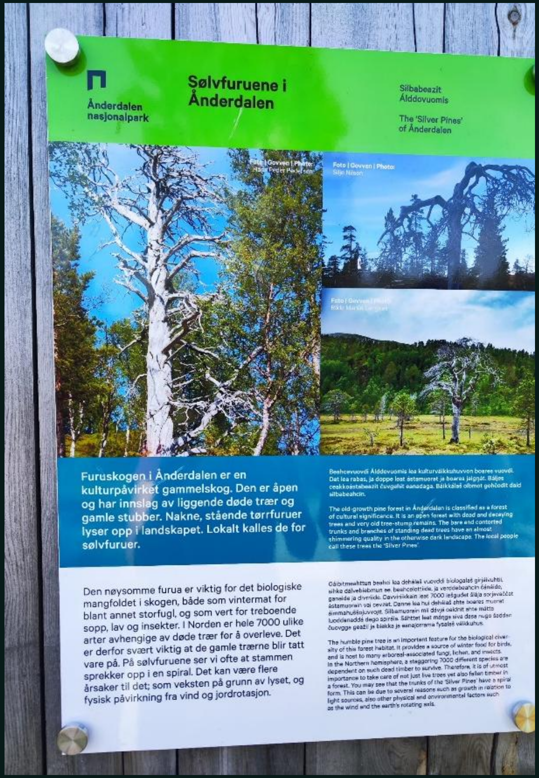
• Contributes to the implementation of the Spanish Forest Strategy and the integration of mature forests into territorial planning.

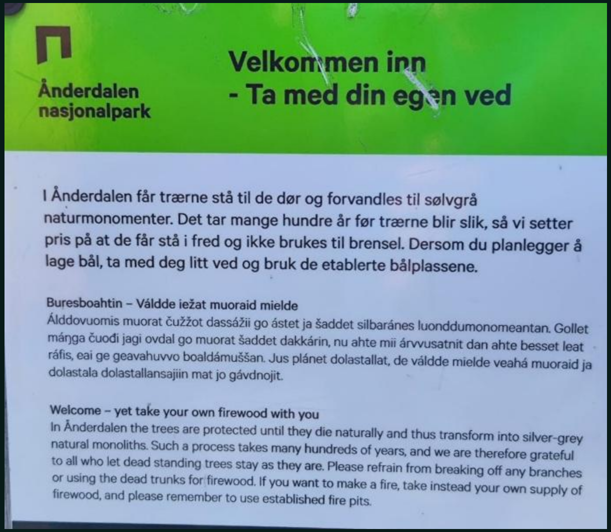



Slide from: Microsoft PowerPoint - Jose Atauri.pptx

# Reference Stand Map – Red Bosques Project (redbosques.creaf.cat/redbosques/herramientas#mapaFase1)

# Anderdalen National Park-Norway




# Old Growth Forests in Andalusia

**Los Alcornocales Natural Park (Quercus suber)**

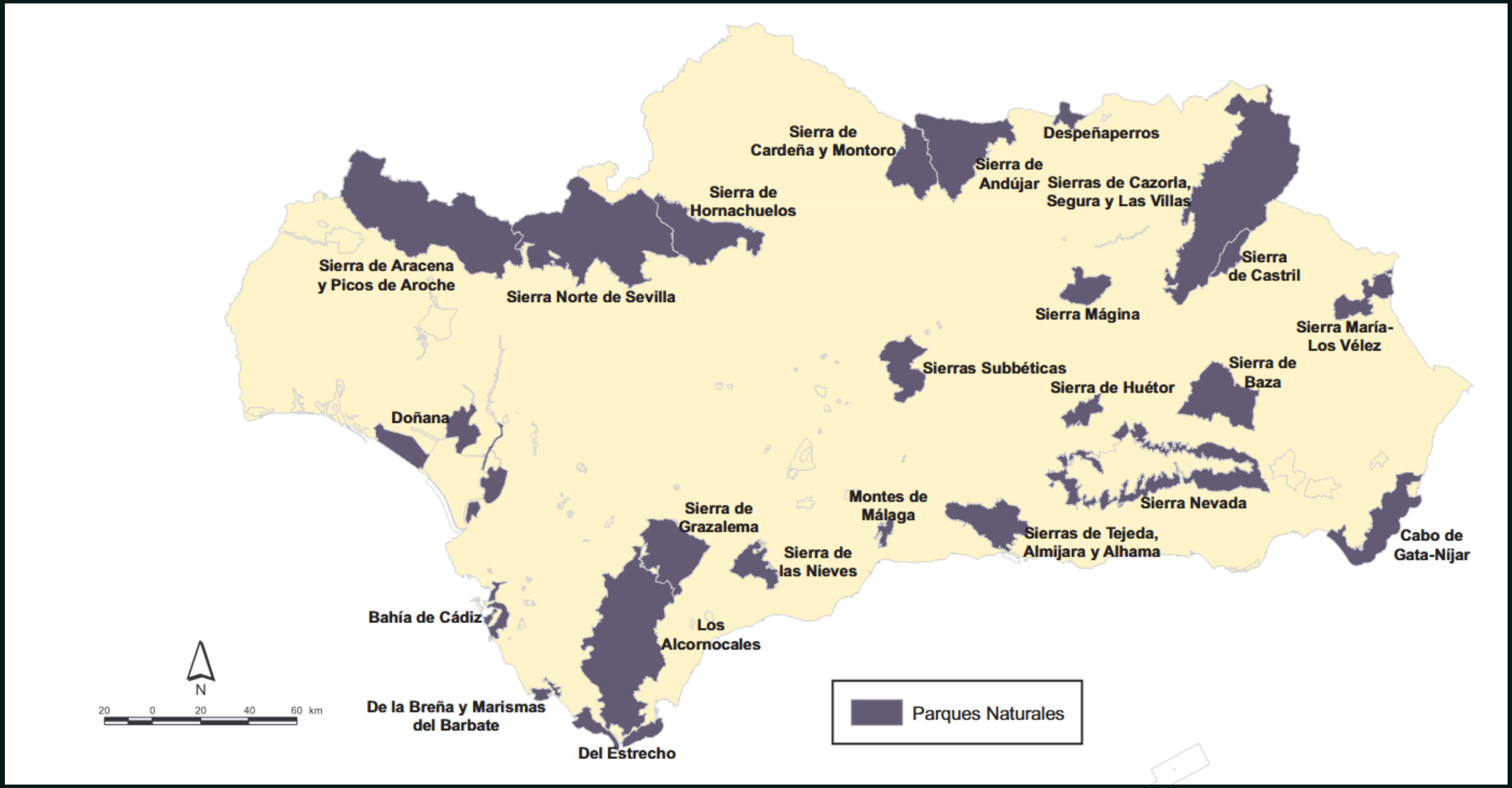
**Sierra de Las Nieves National Park (Abies pinsapo)**

**Sierra Nevada National Park (Pinus sylvestris)**

**Doñana National Park (Pinus pinea)**

**Cazorla, Segura y Las Villas Natural Park (Pinus nigra)**

# Natural and National Parks in Andalusia



# Alcornocales (Cork oak forests)

## Alcornocales Natural Park(1989)

Cork Oak Forests

Cadiz and Málaga province

ZEC Natura 2000

Ecological values, biodiversity and biological corridor between Europe and Africa (Mediterranean Intercontinental Biosphere Reserve, designated by UNESCO in 2006)

# Pinsapares (Abies pinsapo forest)

**Sierra de las Nieves National Park (2021)**

*Abies pinsapo* Forests

Natural Park since 1989

Málaga province

ZEC Natura 2000

Relic fir in the South of Spain and North Morocco

Special Plan for protection of Abies pinsapo in Andalusia since 2011

# Scots pine forests (Pinus sylvestris )

**Sierra Nevada**

**National Park (1999)**

*Pinus sylvestris* forests

Natural Park since 1989)

Granada  province

The Southernmost Scotspine forest in Spain

# Coastal pine forests (Pinus pinea forests in dunes)

## Doñana National Park (1969)

*Pinus pinea* forests on dunes

Huelva and Seville provinces

Biosphere Reserve, ZEPA, LIC, Ramsar, World Heritage UNESCO (1994)

# Bosques de pino salgareño (Pinus nigra ssp. salzmannii )

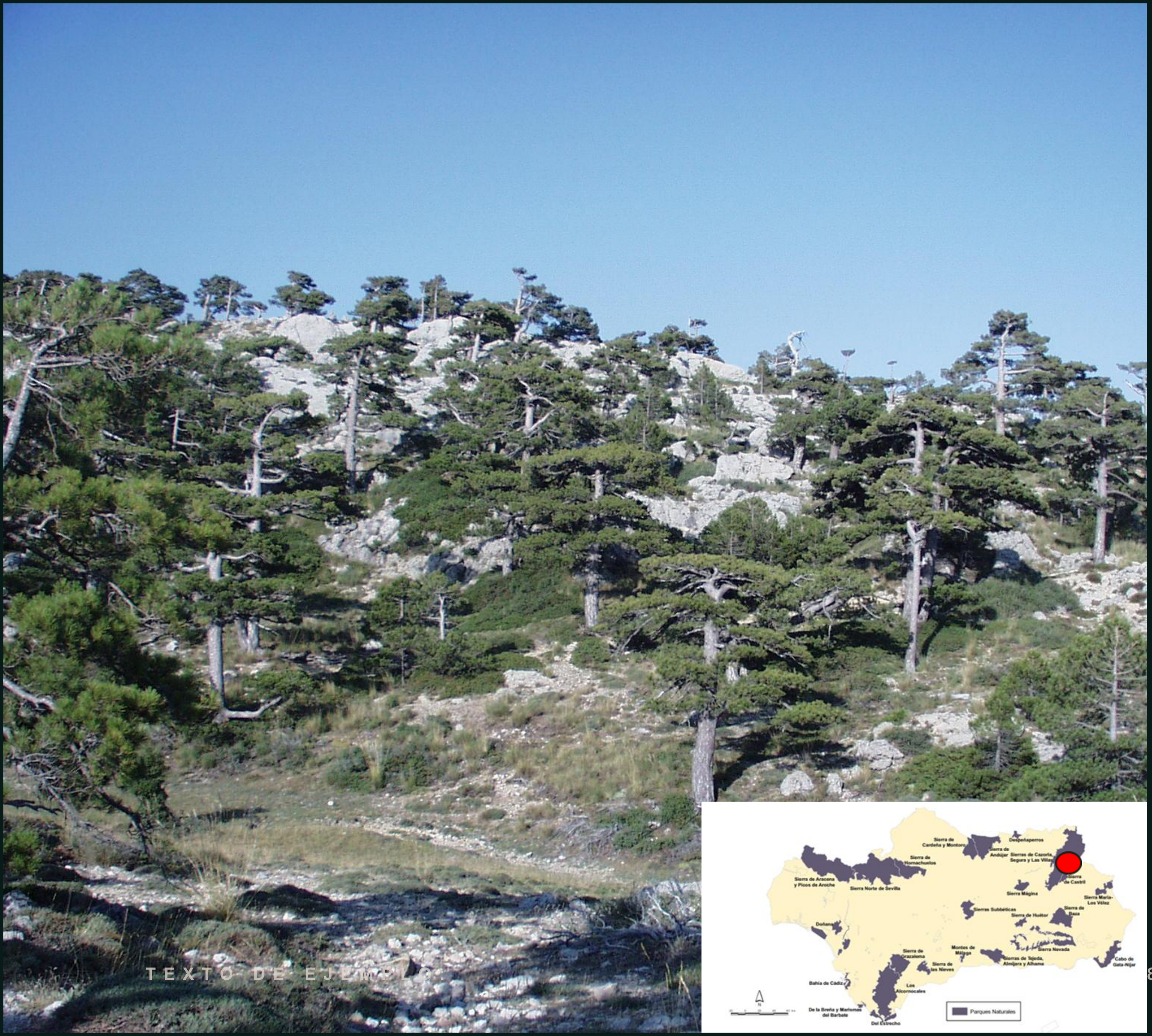
## Cazorla, Segura and Las Villas Natural Park (1986)

*Pinus nigra* forest

Jaén province

ZEC Natura 2000

Oldest forests in the Iberian Peninsula, over 1000 years old



# Research Projects on Old-Growth Forests (UHU)

| Project Title | Main Objectives |
|---|---|
| The End is the Beginning (BEGINPINE, 2023–2026) | Studies regeneration and aging of native pine forests.<br>Analyzes resilience and vulnerability to environmental change.<br>Aims to improve adaptive ecosystem management. |
| End of the Cycle (OLDPINE, 2018–2022) | Investigates senescence, mortality, and regeneration in Mediterranean pines.<br>Evaluates adaptation to climate change.<br>Proposes sustainable forest management strategies. |
| Old Pine Forests in the Face of Climate Change (2016–2018) | Analyzes vulnerability and adaptive capacity of old-growth forests.<br>Studies implications for forest management.<br>Supports conservation policies under climate change. |

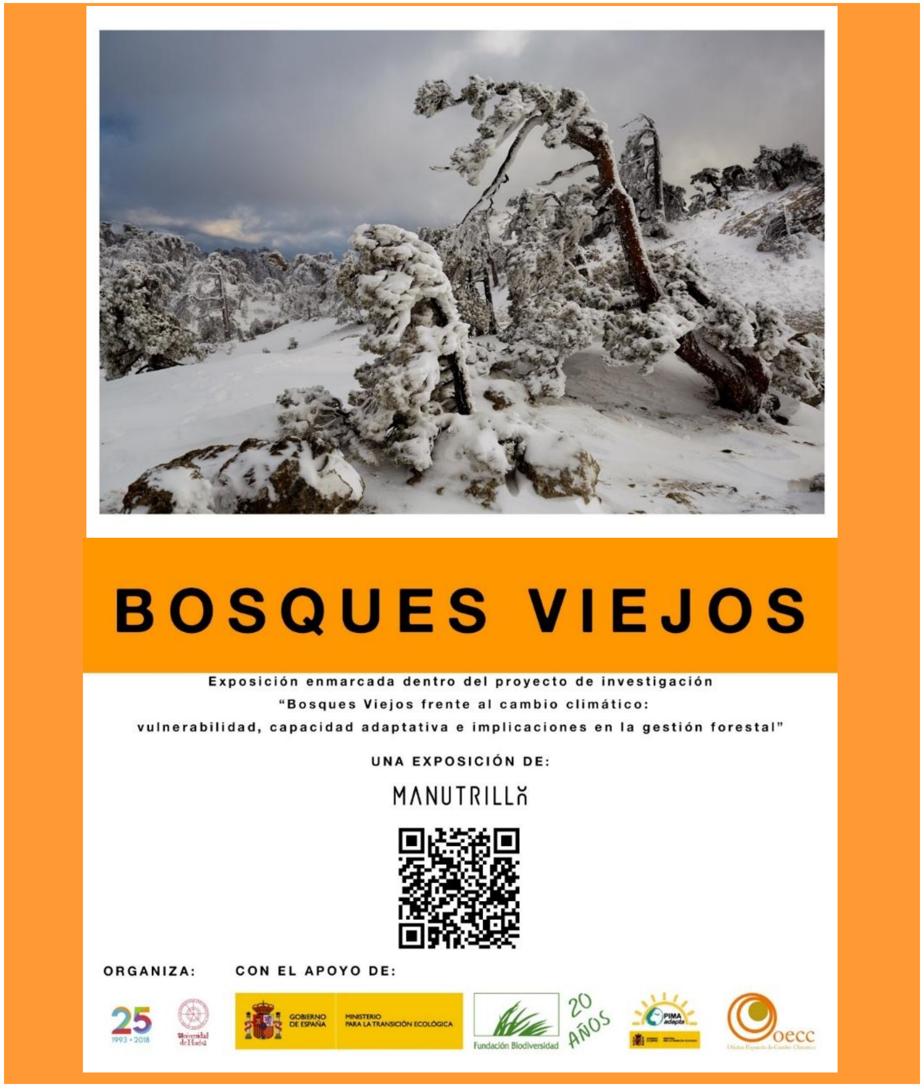
# Research Projects on Old-Growth Forests (UHU)

| Project Title | Main Objectives |
|---|---|
| Vulnerability of Pinus pinea Stands (2014–2017) | Assesses response of Pinus pinea forests to global change scenarios.<br>Identifies ecological and productive risk factors.<br>Suggests adaptation measures for conservation. |
| Millennia Old Black Pines and Andalusian Cultural Heritage (2014–2015) | Explores links between ancient black pines and Andalusian heritage.<br>Studies historical human-environment interactions.<br>Uses dendrochronology to reconstruct landscapes. |
| European Dendrochronology Network to Assess Iberian Wooden Cultural Heritage (2009–2011) | Builds a multidisciplinary network to study Iberian wooden heritage.<br>Strengthens European dendrochronology with Mediterranean data.<br>Supports global cultural heritage conservation. |



- Millennia old black pines and Andalusian Cultural Heritage to unravel human-environment interactions in the Western Mediterranean (National Geographic Waitt Grant)

# DISSEMINATION




# DISSEMINATION

LA NOCHE EUROPEA DE L@S INVESTIGADOR@S | 26/09/2025 Andalucía
MUJERES Y HOMBRES QUE HACEN CIENCIA PARA TI

Sobre La Noche | ¿Quieres participar como voluntari@? | Contacto

Programación | Protagonistas | Noticias

1. Avenida Bulevar de las Artes y las Ciencias | Campus El Carmen

## Historias que los árboles nos cuentan

Organiza: Universidad de Huelva

Huelva
26/09/2025 18:00

Taller
Agricultura, Ciencias de la Tierra, Medio ambiente

Acceso libre

En este taller vamos a aprender a extraer una muestra de un árbol que nos permita leer sus anillos, con un extractor que se llama barrena de Pressler, vamos a dibujar el cronograma (la historia de su crecimiento a lo largo del tiempo) de un árbol, y a partir de él identificaremos algunos eventos climáticos que éste nos cuenta. También observaremos otros instrumentos que permiten estudiar el crecimiento de los árboles, como los dendrómetros de banda o los dendrómetros electrónicos.

En este taller vamos a presentar una ciencia llamada dendrocronología (etimología: dendron, árbol; cronos, tiempo), que nos permite conocer la edad y el crecimiento de los árboles a través de los anillos que aparecen en su madera. Los fustes de los árboles, con sus anillos diferenciados, encierran mucha información muy valiosa que vamos a tratar de descifrar en el taller. El crecimiento de los árboles está por ejemplo muy relacionado con el clima, y en nuestro país hay árboles de más de mil años; la historia climática de ese milenio está contenida en los anillos.

Si pensamos que las primeras estaciones meteorológicas se instalaron a finales del siglo XIX o principios del XX, podemos comprender el gran valor que tiene una reconstrucción climática de un milenio. Los "mapas" de anchura de anillos de crecimiento o cronogramas son también muy valiosos para datar maderas históricas: una muestra de madera de, por ejemplo, un edificio histórico, puede datarse (conocerse la fecha en que se cortó el árbol, la especie e incluso en ocasiones el área geográfica) gracias a la información escrita en sus anillos. Incluso la dendrocronología se ha utilizado para conocer qué factores ambientales (grandes sequías, grandes lluvias, incendios...) contribuyeron al declive de civilizaciones.

**Grupo/Departamento de investigación:**

Ciencias Agroforestales.

**Participan:**

Anabel Calzado Carretero.
Reyes Alejano Monge.
Miguel Montoro Girona.
Javier Vázquez Piqué.

**Lugar:**

Carpas Campus de El Carmen.

**Financiación:**

Ministerio de Ciencia e Innovación. Proyectos de Generación de Conocimiento 2022 (PID2022-136906OB-C22, 143.750 euros).

**Importe de la financiación:**

143.750 euros

**Valor que aporta la investigación:**

En un momento en que estamos viviendo los efectos del cambio climático en diferentes aspectos, en este taller vamos a conocer algunos conceptos básicos de dendrocronología, una ciencia que nos permite realizar reconstrucciones climáticas, que nos ayudan a conocer el comportamiento del clima en el pasado, y entender las reacciones de los arboles a esos cambios, lo que nos guía para comprender mejor los procesos actuales y planificar y desarrollar estrategias para la conservación de nuestros bosques y de los beneficios que ellos aportan a nuestra sociedad. Por tanto el taller contribuirá a la educación del público y a su concienciación e implicación en las temáticas de conservación del medio ambiente y de la salud pública en el actual contexto de cambio global.

La dendrocronología se revela además como una disciplina con interés para las dataciones de madera histórica de edificios, pecios, etc, así como para entender procesos tan complejos como el declive de civilizaciones. Por tanto el taller podrá contribuir a la concienciación del público hacia los grandes impactos que los cambios medioambientales pueden tener en la sociedad.

Con el taller se pretende además sensibilizar el público hacia el importante rol que la ciencia tiene en el progreso de la sociedad y, con especial referencia a la temática tratada, el papel que las ciencias del medioambiente desarrollan en el conocimiento de nuestro planeta y en la conservación de los recursos naturales que benefician a nuestra sociedad.

Investigador@s participantes

Anabel Calzado Carretero
Ciencias de la Tierra | Huelva
Ver perfil

Reyes Alejano Monge
Ciencias de la Tierra | Huelva
Ver perfil

Javier Vázquez Piqué
Ingeniería | Huelva
Ver perfil

Miguel Montoro Girona
Medio ambiente | Huelva
Ver perfil

GranadaDigital
jueves, 21 de agosto de 2025
Únete

GRANADA | PROVINCIA | CULTURA | DEPORTES | VÍDEOS | GALERÍAS | SUCESOS | PODCAST | VIRAL

ÚLTIMAS NOTICIAS onistas de la agenda musical | Arrestan a un vendedor por estafar a una anciana durante seis años | Contr

GRANADA

## Científicas andaluzas difunden su trabajo en un 'Café con ciencia' dedicado a mujeres

Gabinete
07/03/2014 13:38
0

[TIERRA Y MAR- CANAL SUR TV Estudio de los Bosques Viejos de Andalucía]

TREES *will* TELL

NATIONAL GEOGRAPHIC

Three countries
Old forests, People,
Cities

?

Co-funded by the European Union

PIONEER

# Grazie!

*"If you want to go fast, go alone. If you want to go far, go together"*

*African proverb*



# Detection of old-growth forests through satellite images: a case study in a mediterranean mountain range (Cazorla, southeast Spain)

## Structure

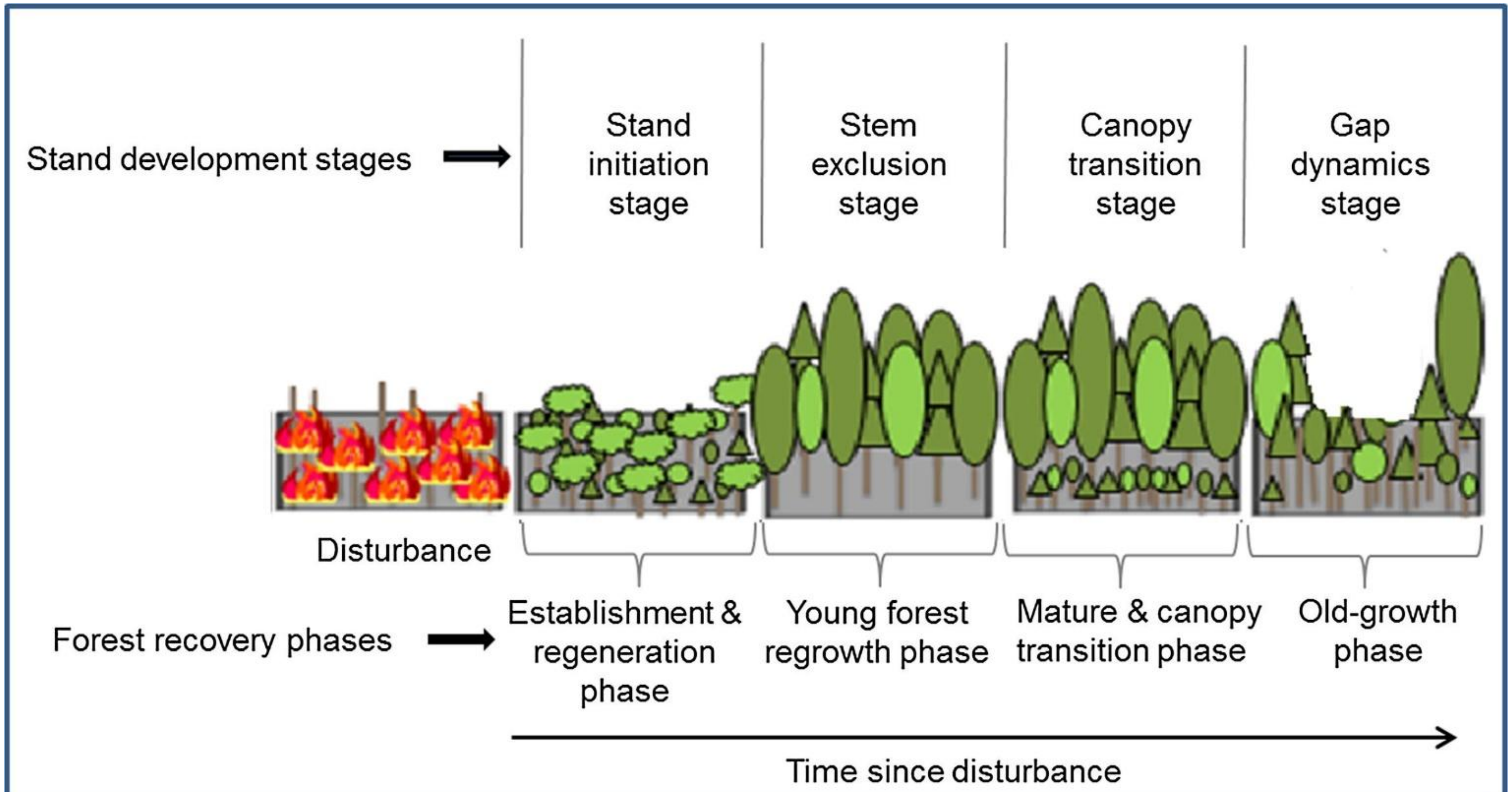
1. **What is an Old-growth forest?**
2. **Detection through structural indexes and satellite images: stydy case in Cazorla mountain range**

¡¡¡Not a single definition!!!

## Three criteria:

- Ecological succesion
- Biogeochemistry
- Structural

# 1. Ecological succesion



# 1. Ecological succesion

**Limitations:**

- **To know the "forest history"**
- **To know the disturbance regime**



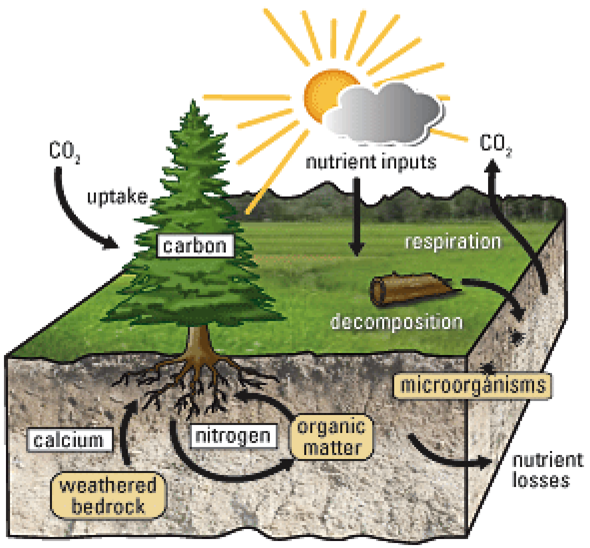
# 2. Biogeochemical criteria

## Caracteristics:

- Closed nutrient cycle
- NPP very low
- Net biomass accumulation quite low
- Increase under-canopy vegetation

## Limitations:

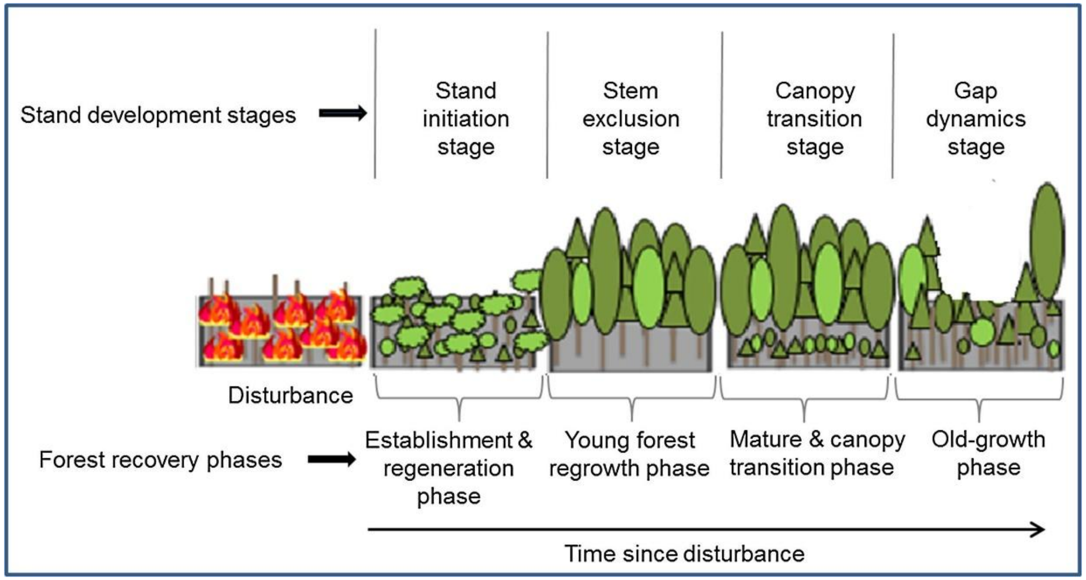
- Very expensive
- Very slow
- A lot of work!!!



# 3. Structural criteria

## Based on:

a. Age distribution
b. Size distribution
c. Spatial distributon patterns of dead and live trees

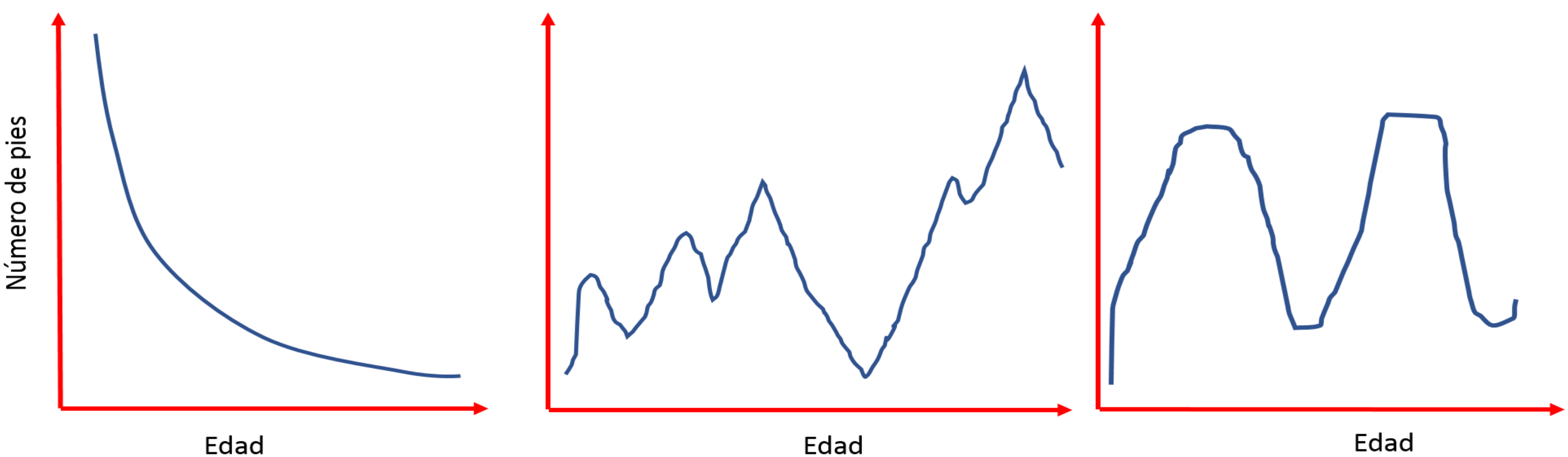



# 3. Structural criteria

## a. Age distributions

Mosseler et al. (2003): main age distributions in OGF:

- Structure inverted-J, irregular or multimodal



# 3. Structural criteria

## a. Age distributions

Mosseler et al. (2003): main age distributions in OGF:

- Structure inverted-J, irregular or multimodal
- Average age of dominant trees around half of the species longevity
- Some old trees close to the maximum longevity

# 3. Structural criteria

## a. Age distributions

Mosseler et al. (2003): main age distributions in OGF:

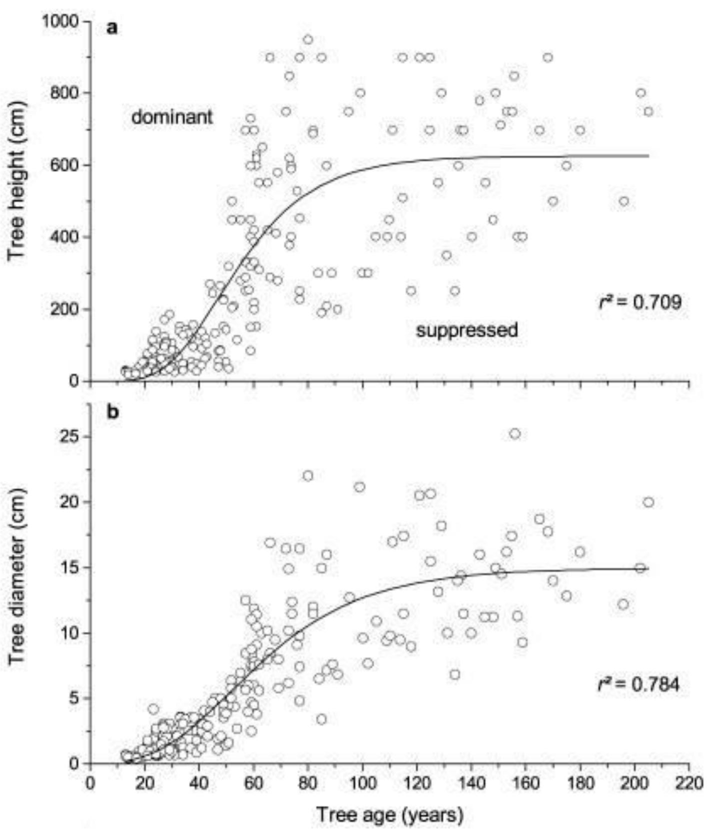
- Structure inverted-J, irregular or multimodal
- Average age of dominant trees around half of the species longevity
- Some old trees close to the maximum longevity



# 3. Structural criteria

## b. Size distributions

Assume a high correlation between age and size

# 3. Structural criteria

## c. Distribution of dead and live trees

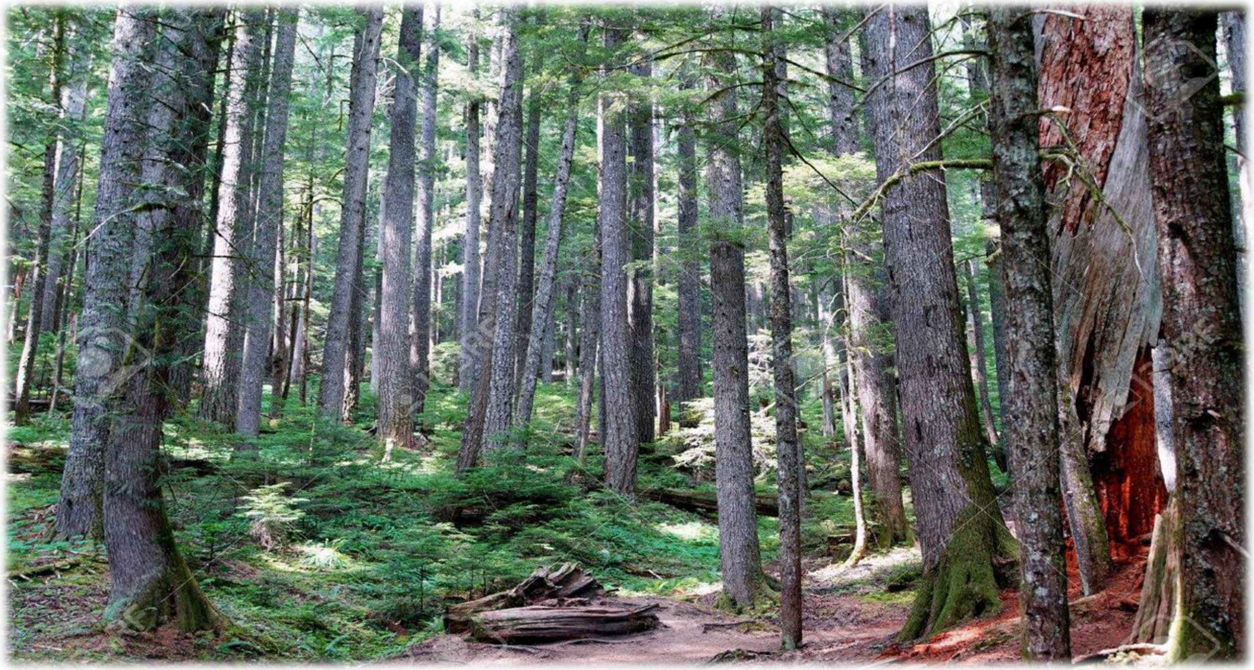
Typical atributes of gap dynamics:

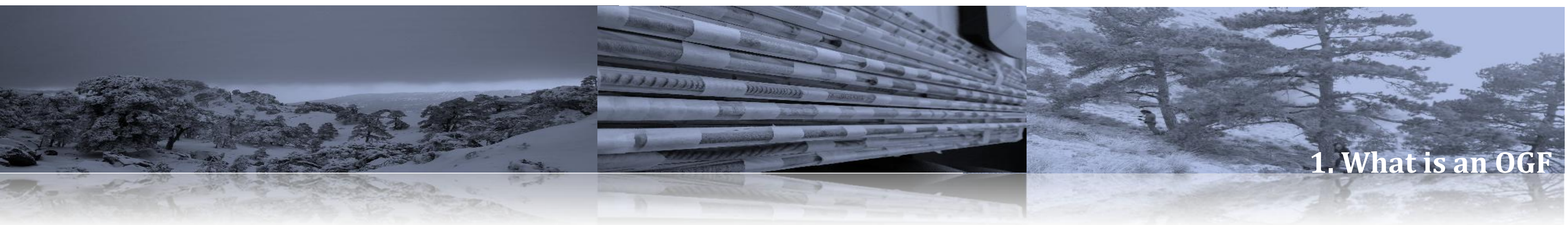
- Presence of mortality
  - Big standing dead trees
  - Big logs of deadwood on the ground

# 3. Structural criteria

## Limitations:

1. Developed for not too many forest types (west coast USA)

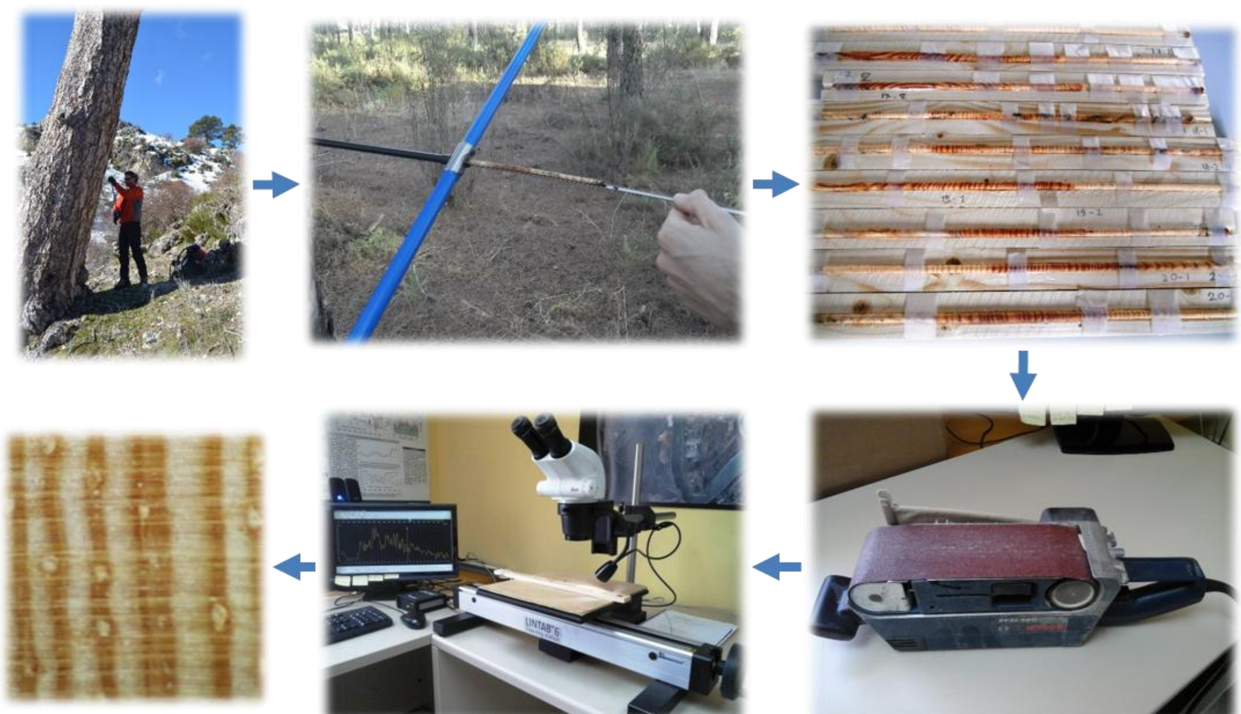





# 3. Structural criteria

## Limitations:

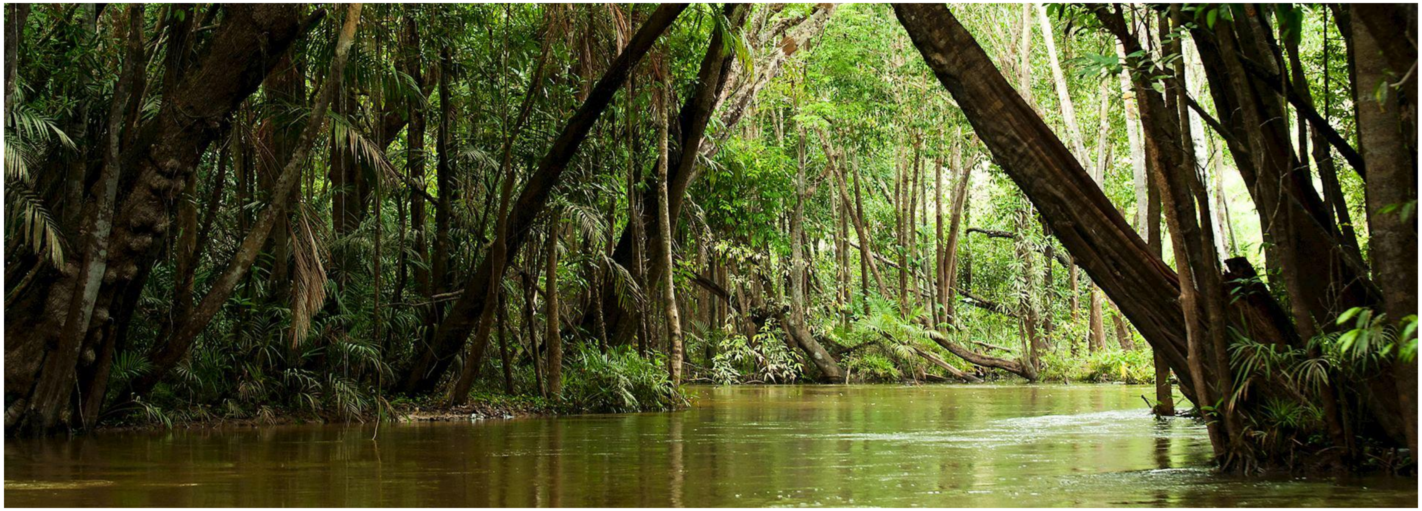
1. Developed for not too many forest types (west coast USA)
2. Problems to determine the age of the trees
    - Costly

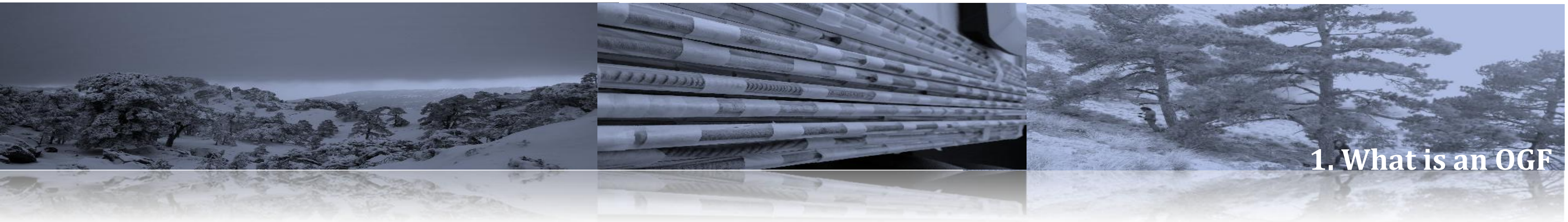


# 3. Structural criteria

## Limitations:

1. Developed for not too many forest types (west coast USA)
2. Problems to determine the age of the trees
    - Costly
    - We cannot distinghish rings in all species



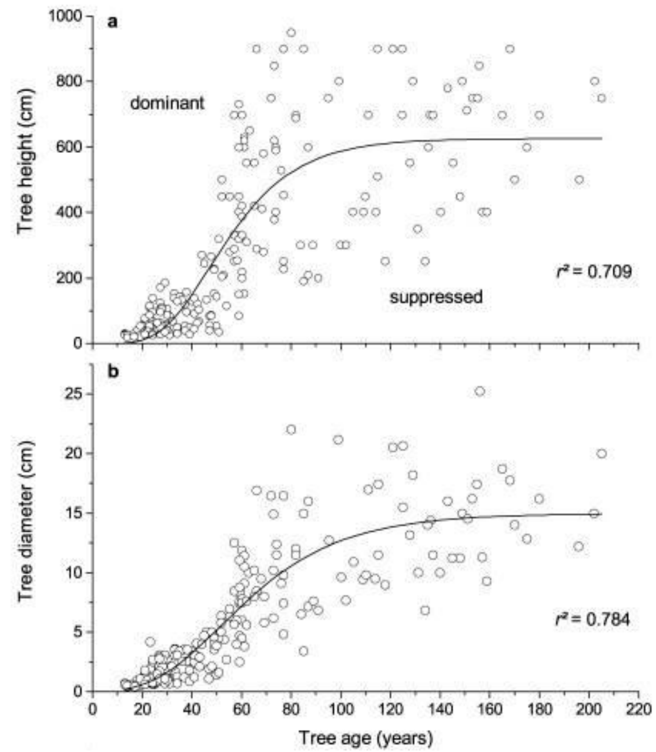




# 3. Structural criteria

## Limitations:

1. Developed for not too many forest types (west coast USA)
2. Problems to determine the age of the trees
    - Costly
    - We cannot distinghish rings in all species
3. Correlation size-age can be low



# 3. Structural criteria

## Limitations:

1. Developed for not too many forest types (west coast USA)
2. Problems to determine the age of the trees
   - Costly
   - We cannot distinghish rings in all species
3. Correlation size-age can be low
4. Deadwood criterion is not always a Good indicator (ecuatorial areas, disturbances)

## 2. Detection through structural indexes and satellite images: stydy case in Cazorla mountain range

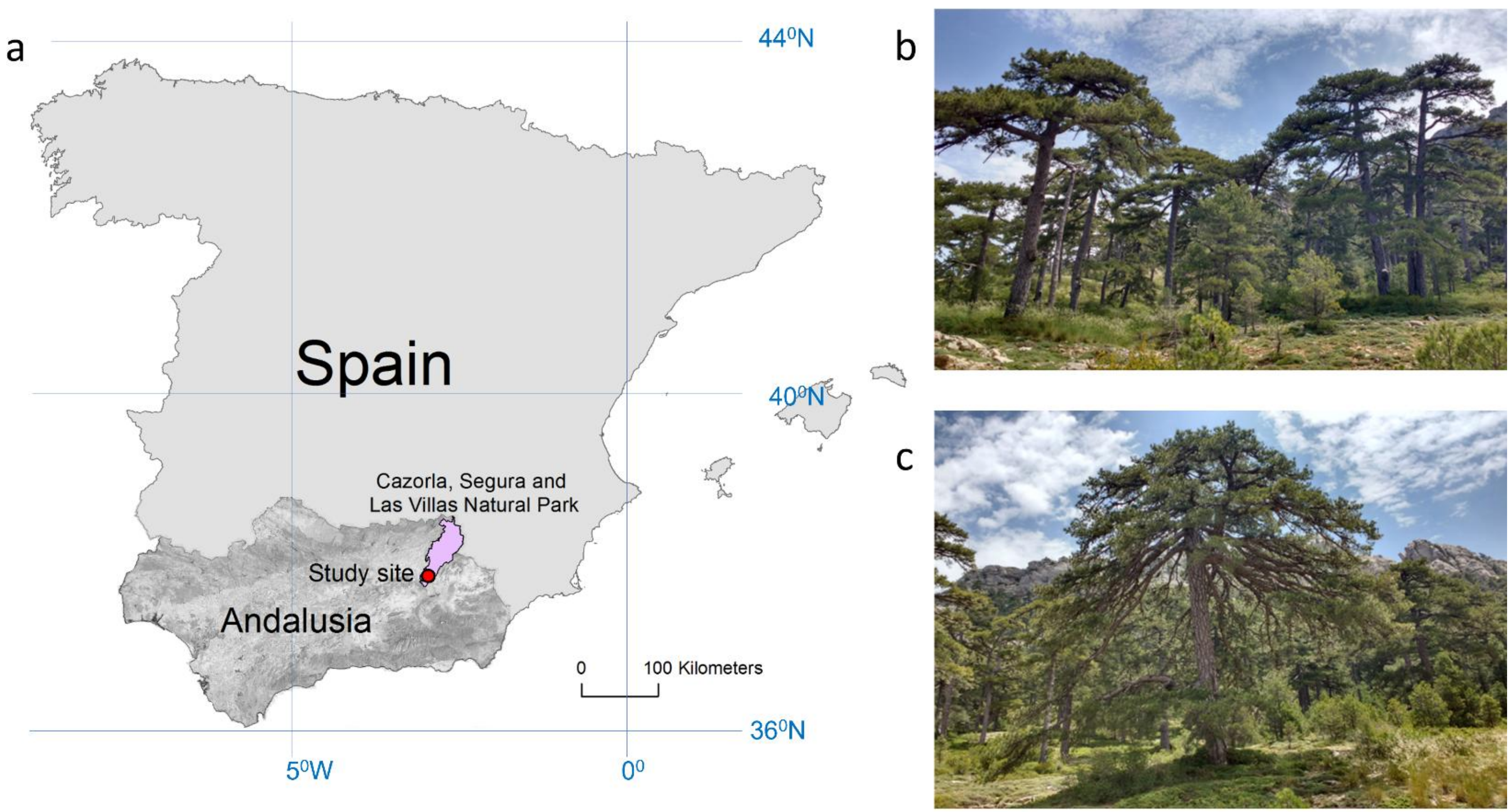
- **Structural criteria**: is the easiest way
- Old-Growth index (OGI)
  - ✓ Number that reflects the maturity of a stand
  - ✓ Obtained from structural variables:
    - Size variability
    - Density of trees exceding a particular diameter (e.g. >70 cm)
    - Mean diameter
    - Total density of trees > e.g. 5 cm
  - ✓ Created for forests of USA west coast
  - ✓ Not widely applied in mediterranean areas

- OGI - Spies y Franklin (1991):

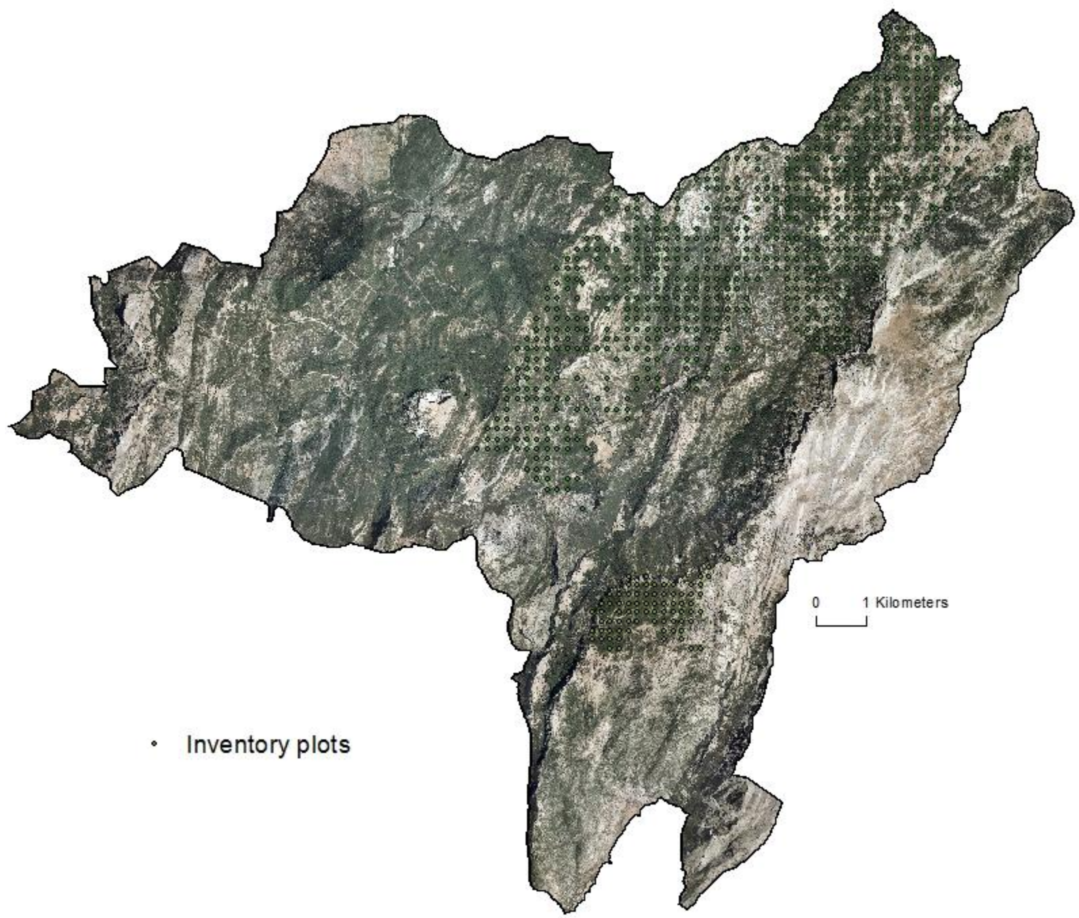
$$OGI = 25 \sum_{i=1}^{i=4} \left| \frac{\mathrm{x}_{\mathrm{i\ obs}} - \mathrm{x}_{\mathrm{i\ young}}}{\mathrm{x}_{\mathrm{i\ old}} - \mathrm{x}_{\mathrm{i\ young}}} \right|$$

- Combination of 4 structural parameters:
    1. Number of trees DBH > 100 cm
    2. Standard deviation of DBH
    3. Mean DBH
    4. Density of trees > 5 cm DBH
- We need to know the characteristic values of the structural parameters for a Young and Old stand

# Study case: Navahondona forest (15 589 ha)

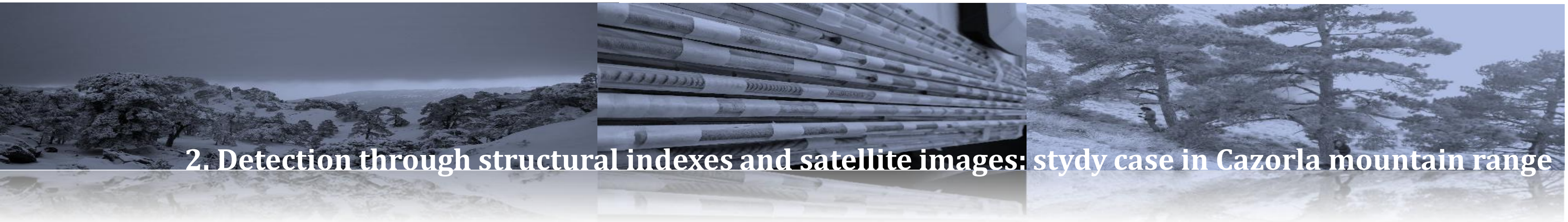


## Study case: Navahondona forest (15 589 ha)



## Study case: Navahondona forest (15 589 ha)

- Inventory data 756 plots (1plot/4 ha)
- Plots >80% *P. nigra.*
- Caracteristic values for  Old stands: inventory of **21 plots**
- Caracteristic values for  Young stands : values for inventory plots with DBH < 20 cm  and P. nigra > 80% (**18 plots**).
- Variations with respect to the original index:
    - Diameter variability: standard deviation and Gini coefficient.
    - Big trees: >50, 70 y 100 cm DBH.
    - Total plot density is not included.

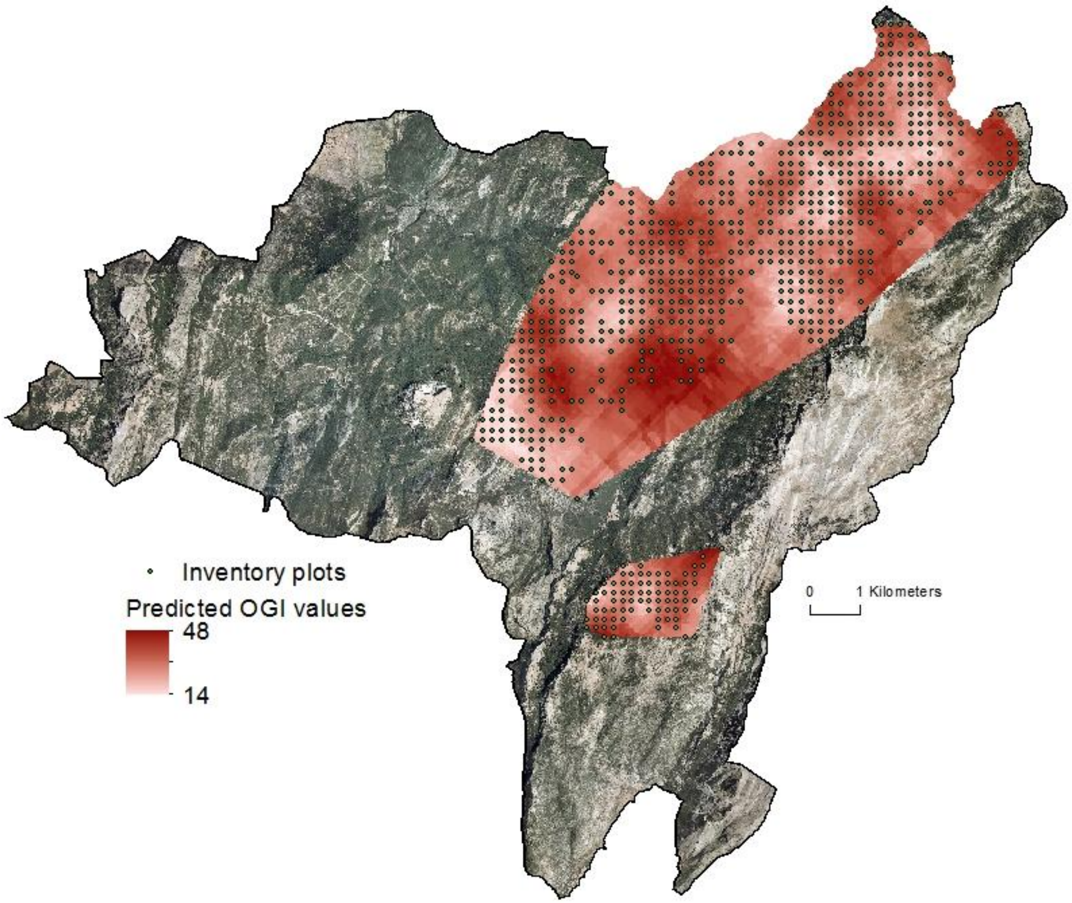


## 2. Detection through structural indexes and satellite images: stydy case in Cazorla mountain range

| Structural variables | Old forest (n=21) | Young forest (n=18) |
|---|---|---|
| Mean DBH (cm) | 70 | 18 |
| StdDev DBH | 31 | 4 |
| Basal area (G, $m^2$ $ha^{-1}$) | 36 | 6 |
| Total density (trees /ha) | 84 | 285 |
| Density of trees > 50 cm DBH | 59 | 0.7 |
| Density of trees > 70 cm DBH | 42 | 0 |
| Density of trees > 100 cm DBH | 12 | 0 |

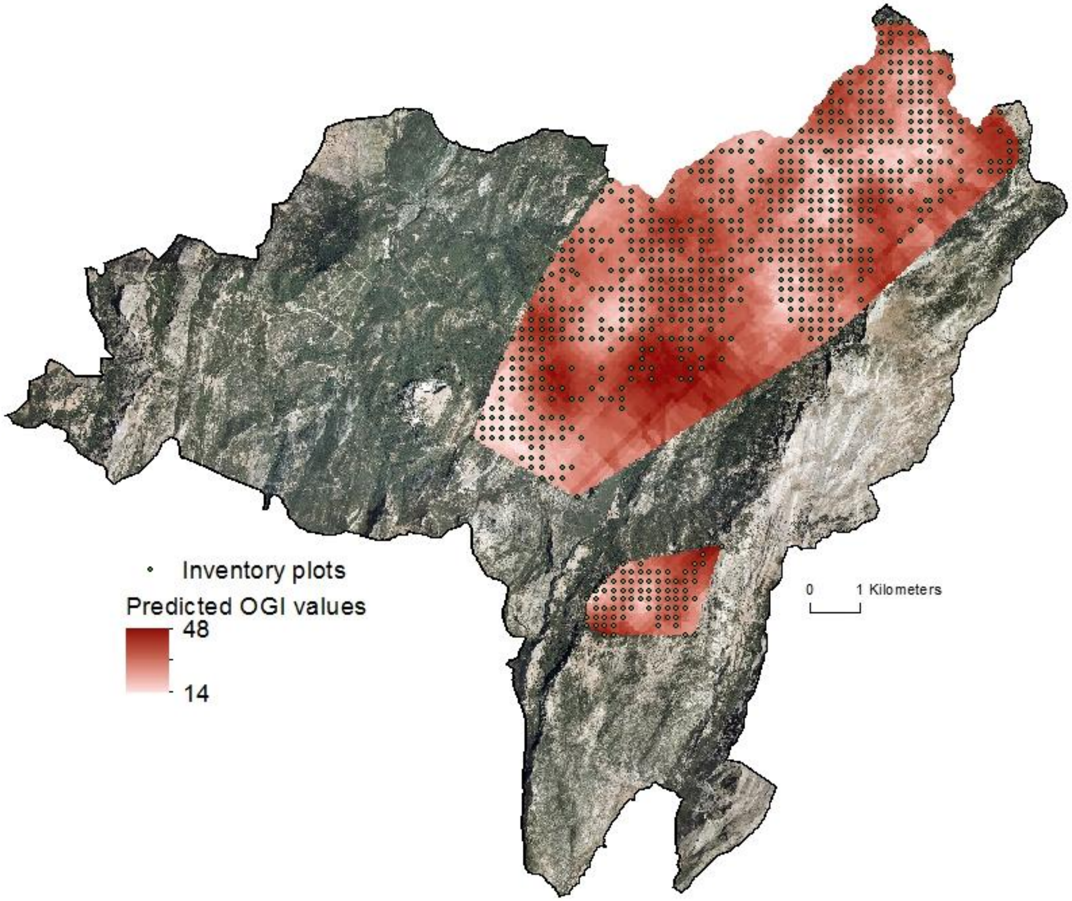
## Study case: Navahondona forest (15 589 ha)

Distribution of OGI in Navahondona by krigging:



## Study case: Navahondona forest (15 589 ha)

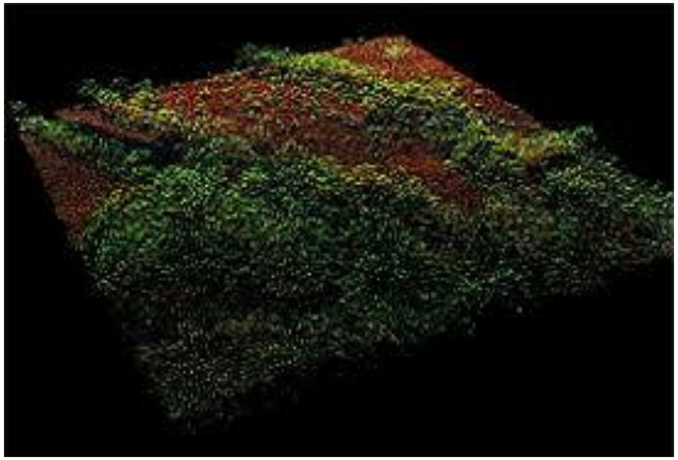
Do the orientation, altitude and slope influence the distribution of OGF?: **No**

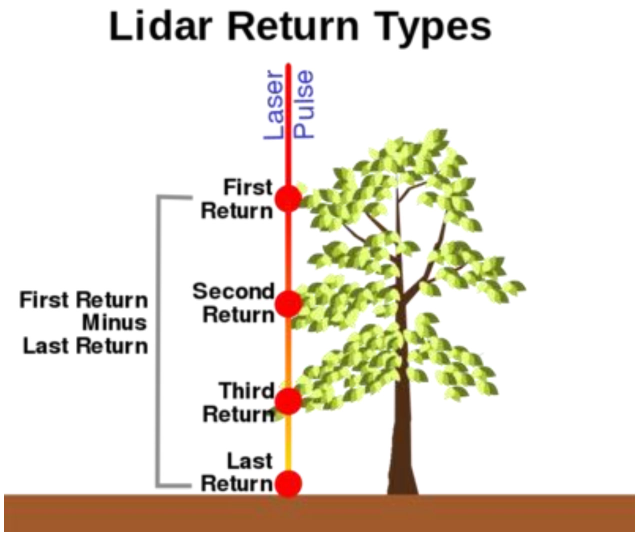


## Study case: Navahondona forest (15 589 ha)

- Limitation of traditional inventory:
  - ✓ Sampling intensity → low to detect some stands
  - ✓ Accesibility of difficult areas

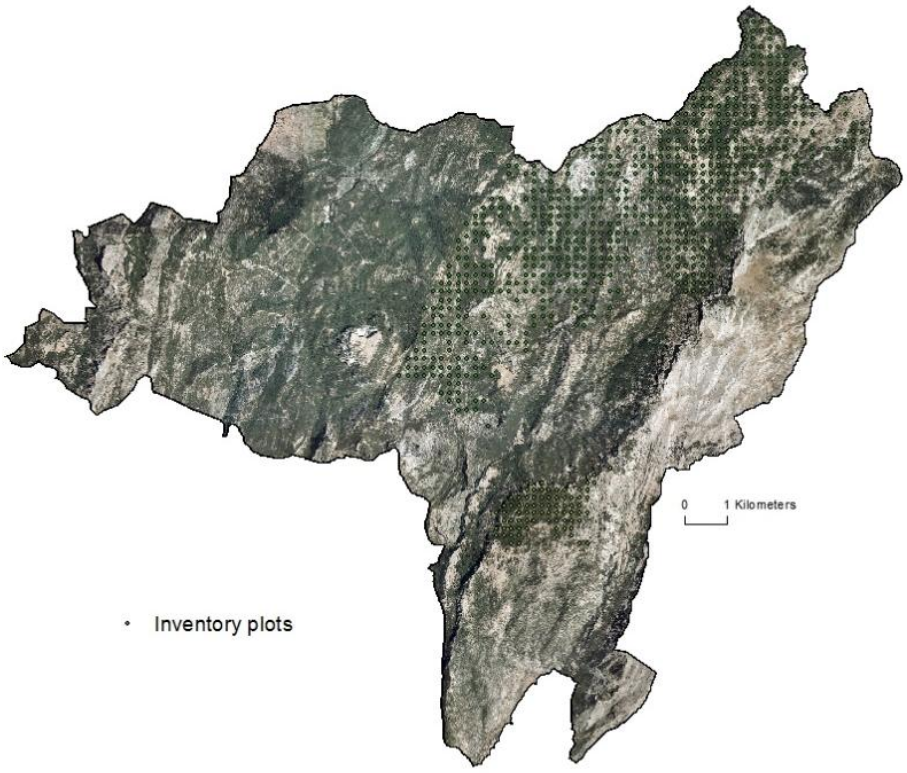
**LiDAR**





## Study case: Navahondona forest (15 589 ha)

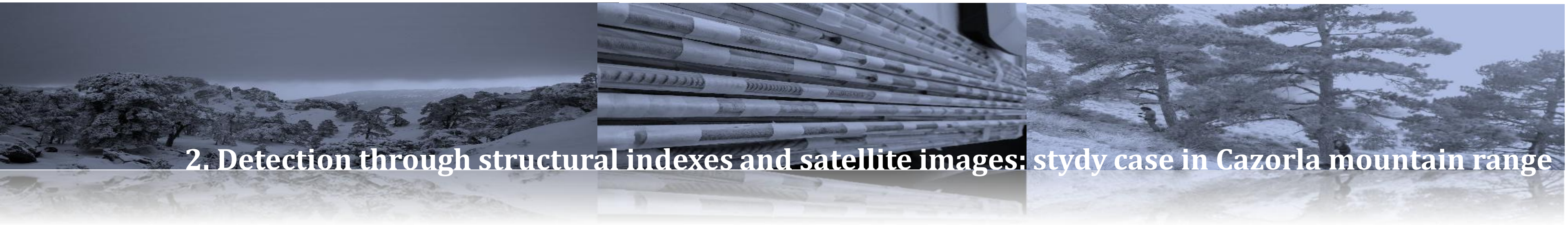
- Data from NCGI:
  - ✓ Density: 2 points/$m^2$



## Study case: Navahondona forest (15 589 ha)

- LiDAR metrics calculated for each plot:

| LiDAR metrics | Description |
|---|---|
| $h_{mean,}$ $h_{mode}$ | mean, mode |
| $h_{min,}$ $h_{max}$ | minimum, maximum |
| $h_{SD,}$ $h_{CV}$ | Std deviation, CV |
| $h_{Skw}$ | Skewness |
| $h_{kurt}$ | Kurtosis |
| $h_{ID}$ | Intercuartilic range |
| $h_{05}$, $h_{10}$, $h_{20}$, $h_{25}$,…,$h_{90}$, $h_{95}$, $h_{99}$ | Percentiles |
| $h_{CRR}$ | canopy relief ratio ((mean height-min height)/max height-min height)) |
| CC | Canopy coverage (percentage of first returns over 4,5 m/total returns) |





## Study case: Navahondona forest (15 589 ha)

- Modelling OGI with LiDAR metrics:

$$OGI = -21.4329 - 0.2741 \times ARAM.TFR + 1.9453 \times P_{95} + 7.9527L_2 + 18.8002 * CRR$$

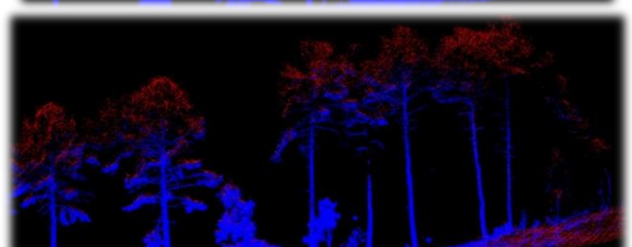
  - ARAM.FTR quotient of all returns over the average  over total of first returns
  - P95: percentil 95
  - L2 : moment of order 2
  - CCR: canopy relief ratio

## Use of satellite data at Natural Park scale

- Modelling OGI and stand atributes with satelite data
  - ➢ First step: Field plots (30) with TLS and dron with LiDAR

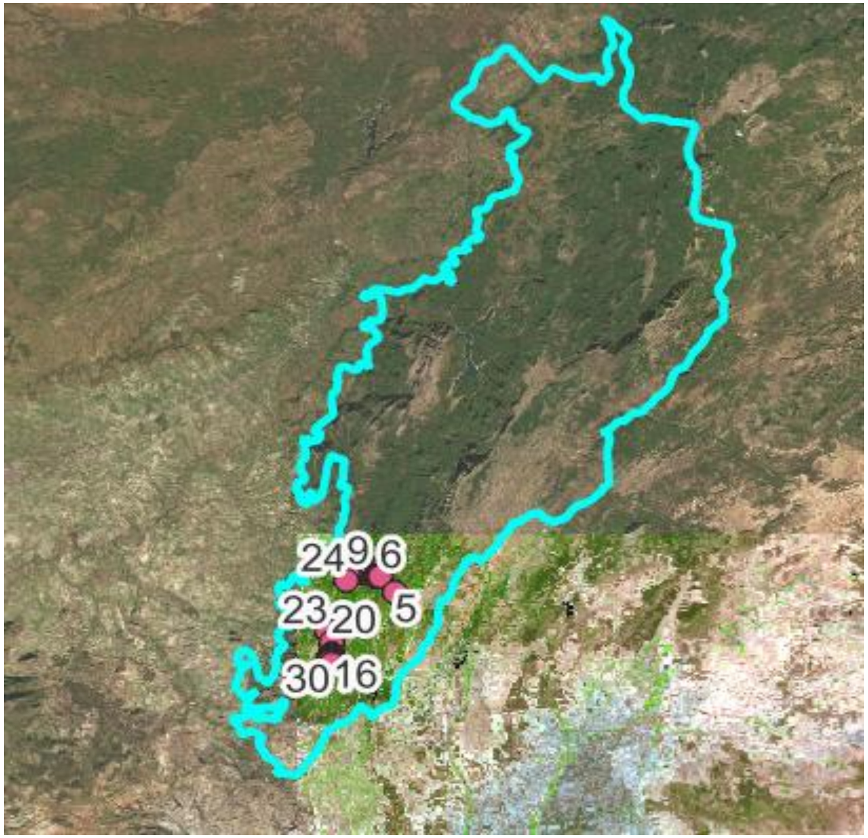


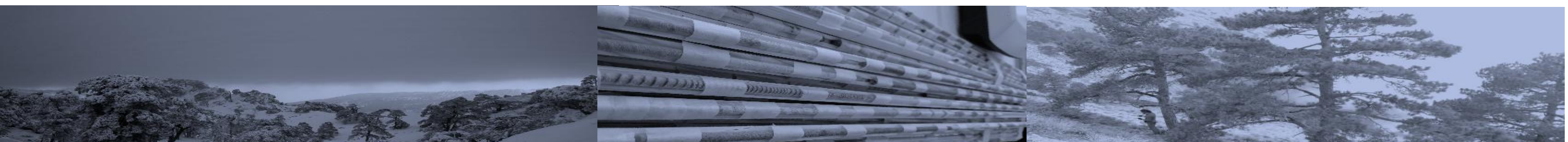


## Use of satellite data at Natural Park scale

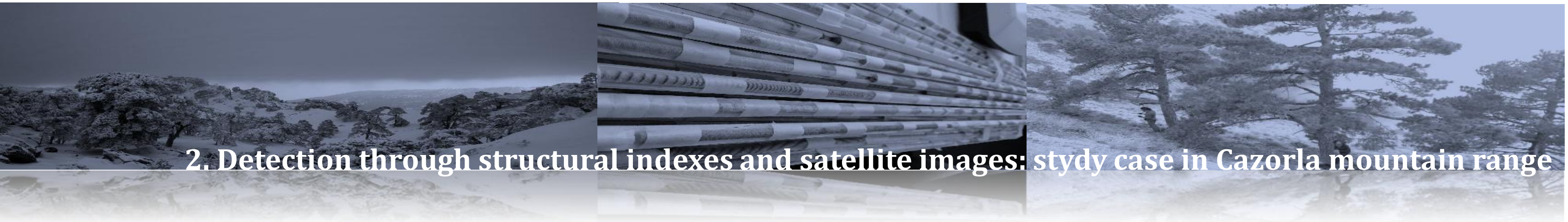
- Modelling OGI and stand atributes with satelite data
  - ➢ Use of free satellite data: Sentinel (10 m pixel)





## 2. Detection through structural indexes and satellite images: stydy case in Cazorla mountain range

| Índex | Description | Formulae | Reference |
|---|---|---|---|
| **NDVI_1** | Normalized Difference Vegetation Index | $\frac{B8-B4}{B8+B4}$ | (Rouse et al., 1974) |
| **NDVI_2** | Normalized Difference Vegetation Index | $\frac{B6-B5}{B6+B5}$ | (Gitelson and Merzlyak, 1994) |
| **MCARI** | Modified Chlorophyll Absorption Ratio Index | $[(B5-B4)-0{,}2*(B5-B3)]*\left(\frac{B5}{B4}\right)$ | (Chaoyang Wu et al., 2008) |
| **NDGI** | Normalized Difference Generic Index | $\frac{B8-B5}{B8+B5}$ | (Pasqualotto et al., 2018) |
| **LAI** | Leaf Area Index | | |
| **FAPAR** | Fraction of Absorbed Photosynthetically Active Radiation | Biophysical Processor de SNAP | |
| **fCover** | Vegetation cover fraction | | |
| **LCI** | Leaf Chlorophyll Index | $\frac{B8-B5}{B8+B4}$ | (Cardim & Lima, 2019) |
| **EVI** | Enhanced Vegetation Index | $\frac{2{,}5*\ (B8-B4)}{\big(B8+\ (6*B4)\big)-\big((7{,}5*\ B2)+1\big)}$ | (Huete et al., 2002) |
| **MSAVI** | Modified Soil-Adjusted Vegetation Index | $\frac{2*\ B8+1-\ \sqrt{(2*\ B8+1)^2-8*\ (B8-B4}}{2}$ | (Qi et al., 1994) |
| **IRECI** | Inverted Red-Edge Chlorophyll Index | $\frac{B8-B4}{\frac{B6}{B5}}$ | (Frampton et al., 2013) |

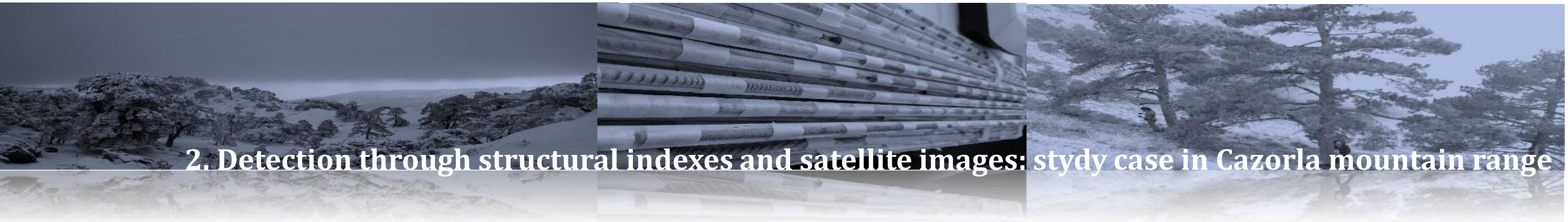



## Use of satellite data at Natural Park scale

- Modelling OGI and stand atributes with satelite data
  - ➢ Use of free satellite data: Sentinel (10 m pixel)

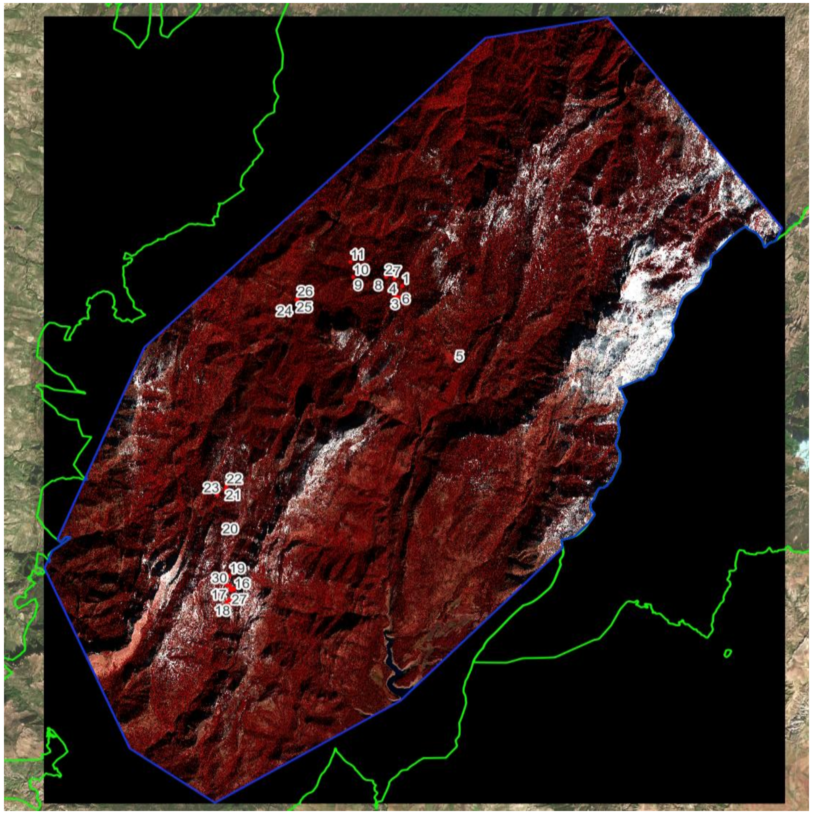
$$OGI = 168{,}8 - 287{,}5 * NDGI \qquad R^2 = 0.18$$

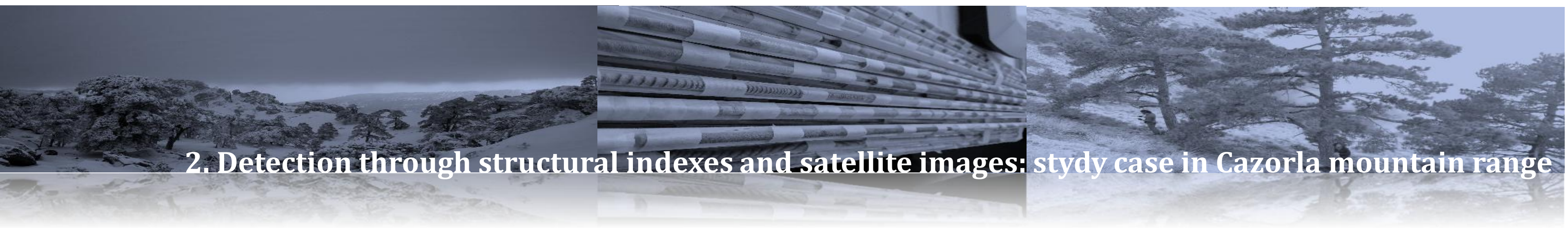
- Vegetation indices most correlated with the OGI are NDGI, LCI, and IRECI
- These indices incorporate the NIR and Red Edge bands in their formulation, which are sensitive to canopy structure (NIR) and leaf density or chlorophyll content (Red Edge)—both factors closely related to canopy cover.
- The fraction of canopy cover (Fcc), measured with TLS, showed a strong negative correlation with OGI ($R = -0.71$, $p < 0.01$), reflecting lower coverage in mature forests due to natural clearings.




## Use of satellite data at Natural Park scale

- Modelling OGI and stand atributes with satelite data
  - ➢ Next step : use of high resolution Worldview-3 satellite data (30 cm resolution)





## 2. Detection through structural indexes and satellite images: stydy case in Cazorla mountain range

| Variable | Descripción |
| --- | --- |
| NDVI_1a | Normalized Difference Vegetation Index |
| NDVI_1b | Normalized Difference Vegetation Index |
| NDVI_2 | Normalized Difference Vegetation Index |
| MCARI | Modified Chlorophyll Absorption Ratio Index |
| NDGI | Normalized Difference Generic Index |
| LCI_NIR1 | Leaf Chlorophyll Index |
| LCI_NIR2 | Leaf Chlorophyll Index |
| EVI | Enhanced Vegetation Index |
| MSAVI | Modified Soil-Adjusted Vegetation Index |
| IRECI | Inverted Red-Edge Chlorophyll Index |
| ISE | Stress index |
| IHD | Wetness index |
| IHD_Yellow_NIR1 | Wetness index NIR1 |
| IHD_Yellow_NIR2 | Wetness index NIR2 |
| YI | Yellow Index |
| fcc_PNOA_OL | Fcc from PNOA MS y PNOA ALS. |
| fcc_PNOA_Ortho | Fcc from PNOA MS. |
| fcc_WV3 | Fcc from WV3. |
| Fcc_TLS | Fcc from TLS. |
| fcc_ALS_TLS_CloudC | Fcc from cloud points TLS-ALS. |

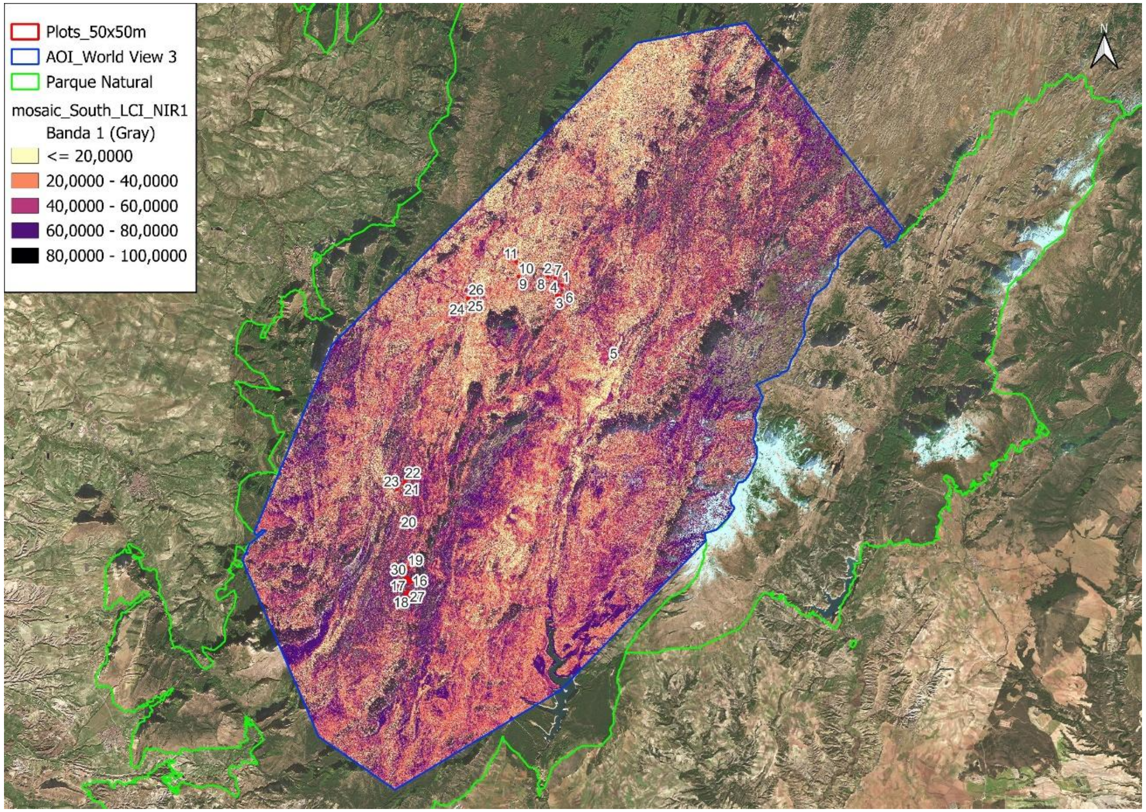
## Use of satellite data at Natural Park scale

- Modelling OGI and stand atributes with satelite data
  - Next step : use of high resolution Worldview-3 satellite data (30 cm resolution)

| VARIABLES | RSQ |
|---|---|
| +FCC_TLS | 0.50 |
| +LCI_NIR1 | 0.47 |
| +IRECIWV3 | 0.46 |
| +NDGI | 0.46 |
| +IHD_NIR1 | 0.46 |
| +IHD_NIR2 | 0.45 |
| +LCI_NIR2 | 0.45 |
| +IHD | 0.45 |
| +MSAVI | 0.44 |
| +FCC_TLS+ISE | 0.51 |
| +FCC_PNOA+LCI_NIR1 | 0.56 |
| +FCC_PNOA+IHD_NIR1 | 0.56 |
| +FCC_PNOA+NDGI | 0.55 |
| +FCC_PNOA+IRECIWV3 | 0.56 |
| +FCC_PNOA+IHD | 0.55 |
| +FCC_PNOA+IHD_YNIR2 | 0.55 |

## Use of satellite data at Natural Park scale

- Modelling OGI and stand atributes with satelite data
  - ➢ Next step : use of high resolution Worldview-3 satellite data (30 cm resolution)



## 2. Detection through structural indexes and satellite images: stydy case in Cazorla mountain range

**Grazie!!!**