Field trip

3rd May 2023

Organised for

FIRE-ADAPT

In collaboration with

FIRE-RES
Innovative technologies & socio-ecological-economic solutions for fire resilient territories in Europe

Universitat de Barcelona

Universitat de Lleida

Diputació Barcelona

This project has received funding from the European Union's H2020 research and innovation programme under grant agreement No 101000289.

General information

- **Organisers:** Forest Science and Technology Centre of Catalonia (CTFC) and University of Barcelona (UB) with the collaboration of University of Lleida (UdL) and Diputació de Barcelona (provincial Council).
- **Date:** 3rd May 2023.
- **Time:** departure at 8.00 from CTFC. Return will be at around 6 pm.
- **Guided by:** Pere Casals, Lena Vilà-Vilardell, Jordi Garcia-Pausas, Gustavo Tudela Haberland, Pere Rovira (CTFC); Xavier Úbeda (UB); Lluis Coll (UdL)
- **Contact:** pere.casals@ctfc.cat; xubeda@ub.edu

Locations

In this field trip we will visit two locations (Fig. 1), addressing two general topics:

1. **Llobera** WP4 study site: Effects of different forest management options to reduce wildfire hazard on forest resistance to wildfire and drought, and indirect effects on soil C stocks and dynamics.
2. **Wildfire in Santa Coloma de Queralt**: Wildfire effects on soils and post-fire management activities for soil protection and forest regeneration.

Other information

The first stop is a short walk (2 km round trip, 55 m of ascent) from the bus through a forest road. Please be prepared for outdoor conditions: comfortable clothes and sport/mountain shoes. Weather is unpredictable in April, so we can find a cold morning in Solsona but a very warm and sunny afternoon in the second location.

Before the first stop, a brief stop for a coffee and other necessities is planned (by 10 a.m.). Lunch is planned at “La Panadella” rest area facility (with restaurant and toilet facilities) at 2 p.m. A packed lunch will be provided.

Figure 1. Location of the two sites (red points): Llobera forest stands, near Solsona, and the Santa Coloma de Queralt wildfire, near Igualada. The location of the Barcelona's airport is also indicated.

Llobera WP4 study site. First stop.

The aim of this stop is to discuss the effects of different forest management options to reduce wildfire hazard on soil C stocks and dynamics.

The Llobera site belongs to the network of demonstrative forest management stands of the Catalan Forest Owners' Center (CPF) and the Forest Science and Technology Centre of Catalonia (CTFC). Llobera together with the Secanella site are the two Catalan study sites of Holisoils WP4, and they are also part of the integrated fire management experiences addressed in the H2020 FireRes project (https://fire-res.eu/).

Integrated fire management

Integrate fire management strategy aims to optimize fuel treatments (e.g., proportion of landscape treated, frequency and location of treatments) using and combining different tools (fire, mechanical, grazing) with the goal of reducing wildfire intensity and severity. Although fuel treatments seem to have low effect on fire behaviour under extreme fire danger conditions (i.e., extreme wildfire events), fuel management increases the opportunity and effectiveness of fire suppression operations and leads to a reduction in fire severity and impacts on ecosystem components, such as soil and vegetation, even under extreme fire behaviour (Cruz et al. 2022).

Llobera and Secanella demonstrative sites are in the strategic area of Sanaüja valley to control the spread of a potential wildfire driven by southern winds to the north and improve the opportunities for safety fire suppression operations (Figures 2 and 3).

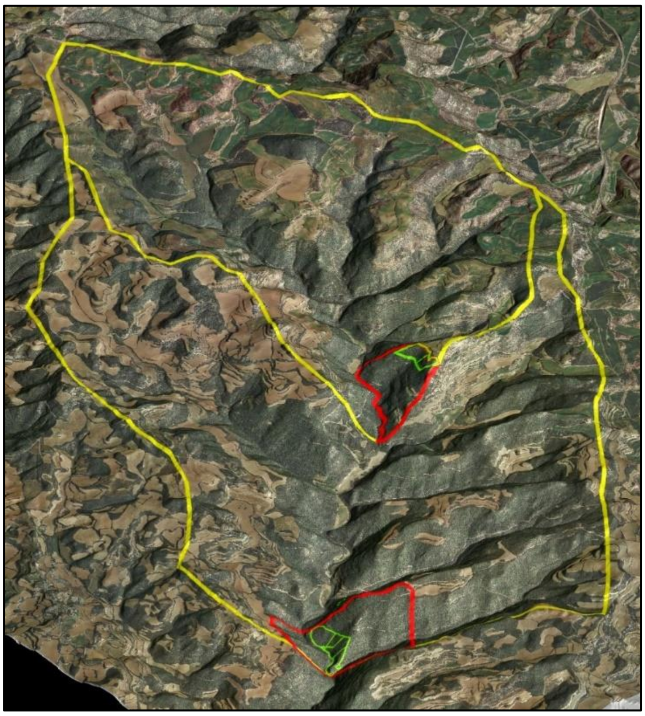

Figure 2. Integrated fire management strategic areas, in red, of Llobera (center) and Secanella (bottom) (in green demonstrative stands) to prevent a potential wildfire (in yellow, expected wildfire perimeter). Font: Catalan Fire and Rescue Service (bombers)

Figure 3. Silvopastoral sytems in Sanaüja valley

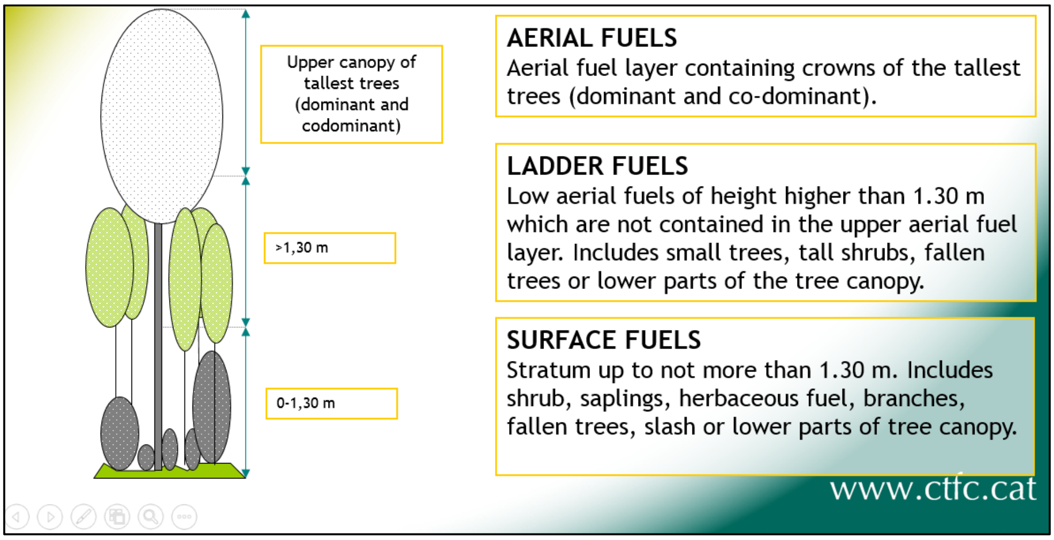

Figure 4. Fuel types are used to classify the stand vulnerability to crown fire (Piqué et al. 2011). Integrated fire management addresses fire hazard by reducing the quantitiy and continuity of fuel

Forest management in Llobera demonstrative site

The Llobera study site is a *Pinus nigra* subsp. *salzmannii* (black pine) forest, with some scattered *Quercus pubescens* (dawny oak) trees. This type of forest is distributed in mountain ranges with sub-Mediterranean climate, mainly in the eastern Iberian Peninsula. These forests are sensitive to high-intensity fires, as this pine species does not produce serotinous cones (Tapias et al, 2001), and the germination of seeds is sensitive to high temperatures (Habrouk et al, 1999). However, their thick bark and the high crown base height confers these pines resistance to low-intensity surface fires (Espinosa et al, 2020). The accumulation of fuel caused by the lack of management has led to an increase of fire intensity, and thus an increased risk for these forests to an eventual high-intensity wildfire. In Llobera, different management options have been tested to reduce the fuel load and to break the vertical fuel continuity, to make these forests more resistant to future wildfires. The following **treatments** were applied in spring 2015 (Figure 5 and table 1):

- High intensity thinning (Hth) with and without burning of debris (Hth B vs Hth U): Final canopy cover 70-75%; basal area reduction 40%
- Low-intensity thinning (Lth) with and without burning of debris (Lth B vs Lth U): Final canopy cover 50-60%; basal area reduction 10%
- Unmanaged control (Control)

The mean temperature at the soil surface during the fire was 450ºC (20-800ºC, n=16) and the mean fire residence time (i.e. time above 60ºC) was 90 minutes (maximum 5 hours).

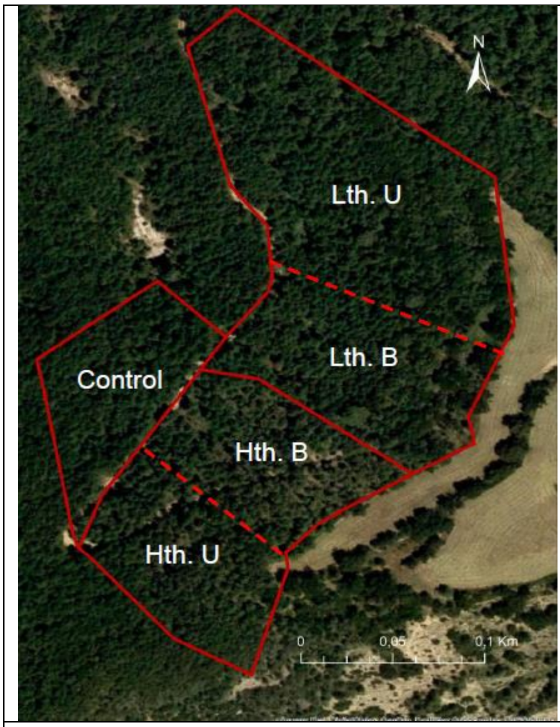

Figure 5. Forest stands at Llobera, with the applied thinning and burning treatments

Table1. Stand characteristics of the *Pinus nigra* subsp *salzmannii* forest stands in Llobera by management treatment, five years after treatments.

		High thinning		Low thinning		Control
		Unburned	Burned	Unburned	Burned	
Plot size	ha	0.4	1.1	1.4	0.7	
Tree density	n ha^{-1}	732	637	1273	1401	1560
Basal area	m^2 ha^{-1}	28.0	24.5	32.1	40.5	39.7
Canopy cover	%	63	52	85	76	89
Shrub cover	%	37	13	52	16	84

Figure 6. Prescribed burning in Llobera (top, left) in spring 2015. After the fire, all fine debris had been consumed (top, right). *Buxus sempervirens* resprouts in the understory, 5 years post-treatment (bottom: burning in the foreground and thinning in the background)

Effects of forest treatments on forest resistance to wildfire and extreme drought events

Four to five years after management, we measured forest structure and fuel load and simulated water balance and fire behaviour under extreme weather conditions. Our aim was to study the effect of forest structure on pine forest vulnerability to extreme drought events and on the potential wildfire behaviour after management, with a special focus on the role of the understory. Results suggest that the resulting mid-term structure following treatments effectively reduced water stress and fire behaviour compared with untreated control, and that the most effective one was where prescribed burning was applied after light or heavy thinning. While understory clearing contributes to increasing the resistance to both disturbances, an additive effect of burning the debris reduced the vulnerability to drought and wildfires after treatments. Our study highlights the importance of managing the understory to further increase forest resistance to both disturbances.

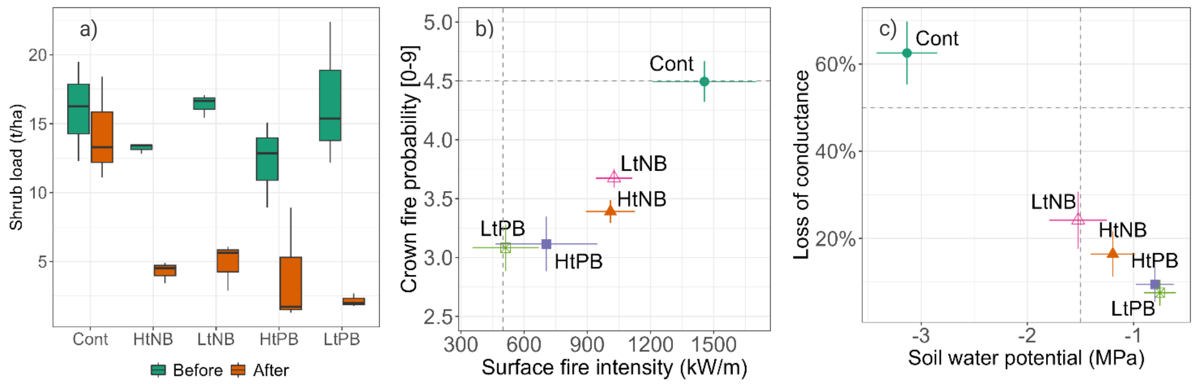

Figure 7. a) Shrub fuel load before and 5 years after treatments; b) Fire behaviour simulation results; c) Water balance simulation results. See more details at Vilà-Vilardell et al 2023. [Cont: Control; HtNB: heavy-thinned not burned; HtPB: heavy-thinned burned; LtNB: light-thinned not burned; LtPB: light-thinned burned]

We are now using dendrochronology and stable isotope techniques to understand the effect thinning and prescribed fire on trees physiological response to drought. For that, we study growth and water use efficiency (WUE) in selected dry years before and after treatments (study in process).

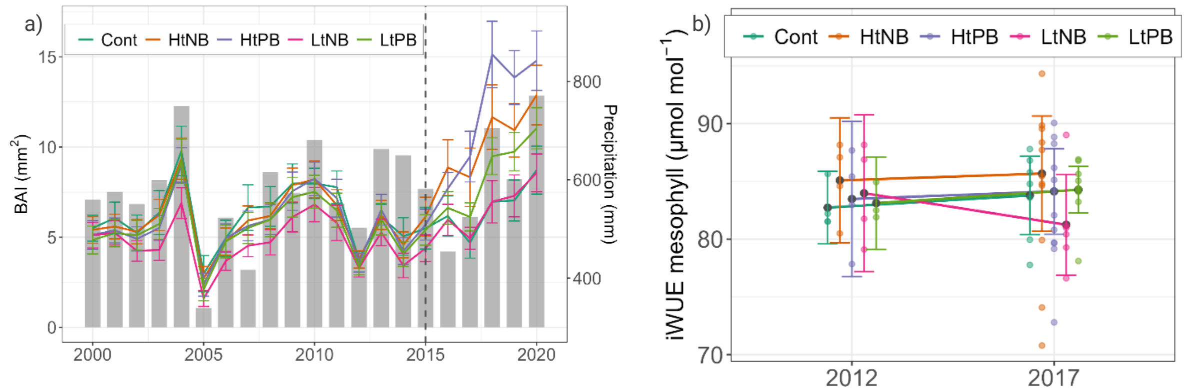

Figure 8. a) Basal area increment (BAI) from 2000 to 2020 per treatment (treatments applied in 2015); b) Intrinsic water use efficiency (iWUE) for a dry year before and after treatments. [Cont: Control; HtNB: heavy-thinned not burned; HtPB: heavy-thinned burned; LtNB: light-thinned not burned; LtPB: light-thinned burned]

Ongoing studies within the framework of HoliSoils WP4

Effects of forest treatments on soil CO_2 efflux

In WP4 we are monitoring soil respiration (CO_2 efflux) of trenched and non-trenched soils at 4 treated stands plus a control in two sites (Llobera and Secanella), using an EGM-5 CO_2 analyzer (PP-Systems).

- Three trenchings (2 m x 1 m, 35-40 cm depth) per stand
- Eight respiration measurement places (4 inside and 4 outside the tren~~n~~chings) at each trenching
- Measurements taken fortnightly (except for winter season) since May 2022

Figure 9. Trenching excavation (top left) and refilling work (top right) in autumn 2021, and respiration measurements being carried out with EGM-5 CO_2 analyzer (PP-Systems) on inserted collars during the 2022 campaign (bottom).

HoliSoils
Working together for forest soils

Effects of forest treatments on soil organic horizons

In the frame of WP4 we aimed to study the effects of different forest treatments on organic carbon (OC) content in the organic layer five years after the treatments.

Soil sampling was performed in 2021, and the sampling design comprised 16 sampling points per stand. At each sampling point, we collected the organic layers (L, F, and H).

Figure 10. Collection of forest floor organic material (L, F and H layers) using frames.

After five years, the treatments applied still affect the organic carbon stocks. The organic carbon amount of thinned and burned stands was lower than the quantity of untreated stands or stands where understory was treated mechanically. Our results suggest that the OC amount is reduced when thinning is combined with prescribed fire, likely due to the decomposition effect by the fire event.

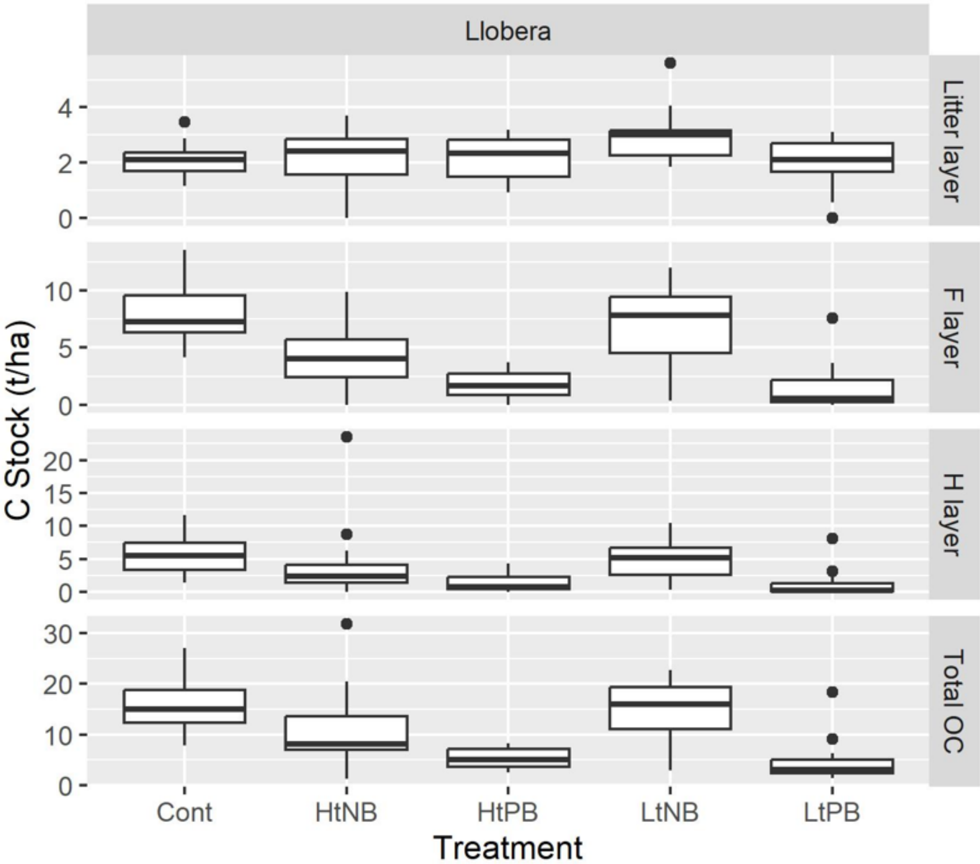

Figure 11. Carbon stocks (t/ha) for all the organic layers analyzed and the total amount of organic carbon for all the treatments applied five years ago. [Cont: Control; HtNB: heavy-thinned not burned; HtPB: heavy-thinned burned; LtNB: light-thinned not burned; LtPB: light-thinned burned]

Subsequently, we will be investigating whether and how the differences in the organic layers influence the catabolic functional diversity of mineral soil.

Characterization of soil organic matter in mineral layers

Physical fractionation of soil organic matter will be performed by wet sieving, in three depth layers (0-5 cm, 5-15 cm and 15-30 cm). Following the scheme below, we will obtain the coarse organic fragments, two sizes of particulate organic matter (POM) and two mineral-associated organic matter (MAOM) fractions. The MAOM fractions (I and II) represents the fine silt + clay sized OM which is associated to minerals by physical and/or chemical interactions (organo-mineral complexes); the difference between them is that MAOM I, released before ultrasonic treatment, involves free organo-mineral complexes, whereas MAOM II involves organo-mineral complexes occluded in aggregates: these aggregates are dispersed during the ultrasonic treatment. Figure 12 shows a diagram of the proposed fractionation procedure.

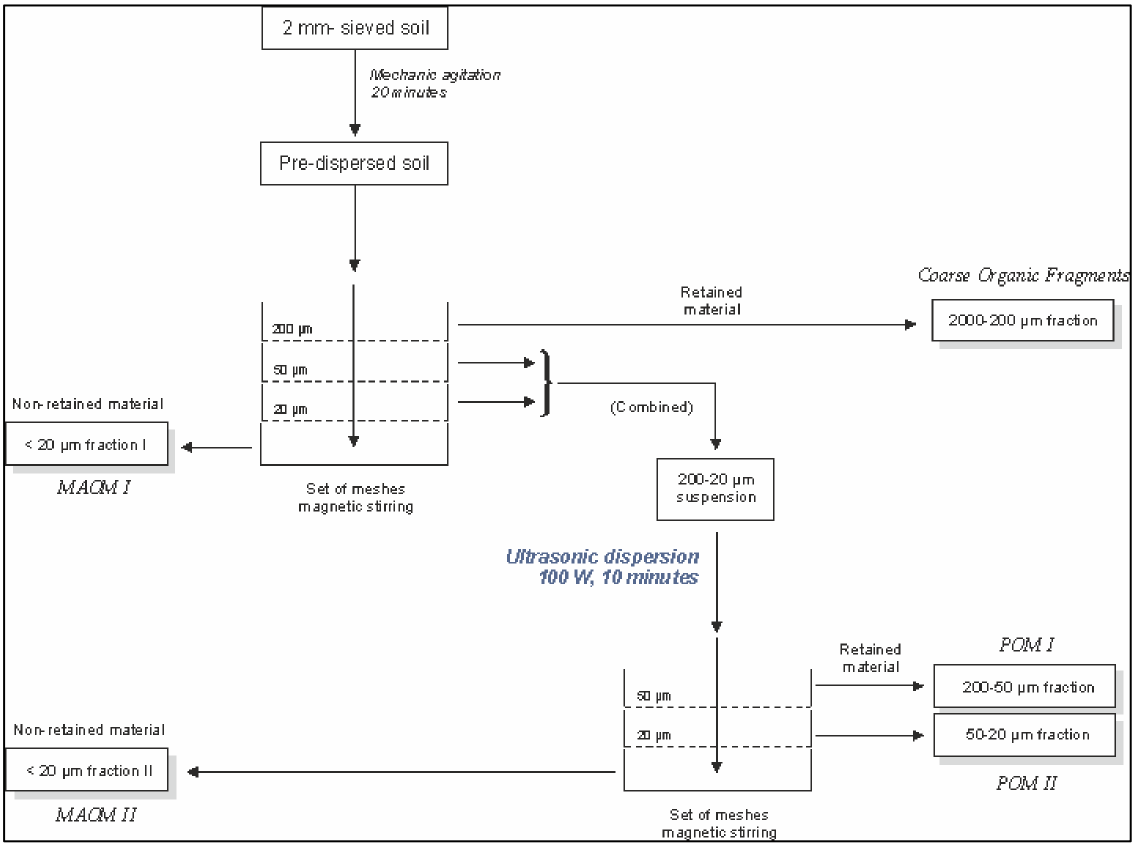

Figure 12. Diagram showing the steps followed for physical fractionation of soil organic matter.

Assessment of the soil functional diversity

Our aim here is to assess the effect of prescribed fires on the microbial functions of surface soils. We are analyzing the community level physiological profiles in surface soils of burned and non-burned plots (thinning vs thinning plus debris burning) by using the MicroResp™ technique (Campbell et al 2003).

The method determines the response (i.e., substrate-induced respiration) to the addition of a set of different organic substrates (i.e., organic acids, carbohydrates, amino acids and phenols). The catabolic functional diversity comes from the respiration response to the addition of each substrate and indicates the capacity of soil communities to degrade biochemically diverse organic compounds. We expect to have an indication of the effect of fire on the microbial soil ecosystem functions.

Santa Coloma de Queralt wildfire (2021, 24th July). Second stop

In this stop we will visit an area affected by a wildfire that occurred in summer 2021, and we will discuss the post-fire activities carried out to protect the soil and restore the vegetation.

Wildfire behaviour

The wildfire started in the afternoon of 24th July 2021 and lasted about two days to be under control and 27 days to be declared suppressed. In the appendix you may find a detailed report of wildfire behavior and extinction operations.

The wildfire affected a total extension of 1,823.90 ha, of which 1,388.84 ha (76%) are forestland (Diputació de Barcelona, 2021), which were *Pinus halepensis* (50%) and *P. nigra* (25%) forests. Most of the forest burned at high intensity and ca. 2 years after natural regeneration is scarce.

Figure 1. Perimeter (red line) of the Sant Coloma de Queralt wildfire occurred on 24th July 2021.

Figure 2. Forest burned at high intensity, and regeneration is still low 20 months after fire (March 2023).

Post-fire restoration

Most of the burned forest is private land that belongs to 58 owners (46% of the forest surface is linked to the Association of Forest Owners of Serres de Miralles-Orpinell).

The Diputació de Barcelona (Barcelona Provincial Council), within the framework of the collaboration agreement with the Serres de Miralles-Orpinell Forest Owners Association, and the Town Halls of their area, in collaboration with the Department of Climate Action, Food and Rural Agenda (Government of Catalonia) and the Catalan Forest Ownership Center (CPF) are leading a post-fire restoration project of the forest affected by the wildfire. The objectives are:

- Post-fire forest planning and management on a landscape (not farm) scale.
- Regeneration of the vegetation cover
- Reduction of the erosion of the soil
- Conservation of soil fertility.


Projecte de restauració de la zona cremada en l'incendi forestal del 24 de juliol del 2021 a la Serra de Queralt i la Serra de Miralles

Bellprat, Santa Maria de Miralles, Sant Martí de Tous, Les Piles, Santa Coloma de Queralt i Pontils.

Diputació de Barcelona

Àrea d'Infraestructures i Espais Naturals
Oficina Tècnica de Prevenció Municipal d'Incendis Forestals i Desenvolupament Agrari

Setembre 2021

Promogut: Diputació Barcelona; Associació de Propietaris Forestals serres Miralles-Orpinell

Amb la col·laboració: Generalitat de Catalunya Departament d'Acció Climàtica, Alimentació i Agenda Rural; Centre de la Propietat Forestal

Figure 4. Postfire restoration project promoted by Diputació de Barcelona

They have designed and delimited 7 types of actions depending on the potential soil erodibility and the intensity of the fire. The main objectives are the stabilization of the burned slopes with natural structures to avoid erosion (Figure 4), and the removal of the burned wood from the accessible areas to facilitate the regeneration of the vegetation (Figure 5).

Figure 5. Actions to reduce post-fire soil erosion in slopes and ravines (Images: VR. Vallejo)

Figure 6. Post-fire regeneration (March 2023): *Pinus halepensis* seedlings (left and center) and *Juniperus oxycedrus* resprouts (right)

Figure 7. Burned tree removal to enhance post-fire natural regeneration in accessible slopes

Estimated budget of post-fire restoration (Diputació de Barcelona, 2021)		
Treatment	**Surface (ha)**	**Cost (€)**
Erosion control	722	554,683
Thinning	1281	1,860,215
Biodiversity	1218	117,932
Forest road arrangement	72.7 km	154,620
Agricultural land recover	8.15	31,557
Total		**2,719,008**

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