# LIFE GoProForMED

## WP3

### Tools for Close to Nature forest management

# *Closer-to-Nature* Forest management models in demonstrative intervention areas in the Mediterranean Region

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# 1. Purpose of the document

The document proposes and describes forest management models in line with the principles of *Closer to Nature* Forest management (CNF).

The **aim** is to **provide alternative and innovative forest management models**, aimed at promoting the best management of target forest habitats, also considering production aspects, and harmonized and cohesive at the level of the Mediterranean Biogeographic Region.

The definition of these intervention models is based on the analysis of the best experiences of different forest management approaches (e.g. irregular, continuous cover, tree silviculture, etc.) in line with the principles of CNF, already applied in the Mediterranean area (T2.3). It should be specified that some of the experiences described are not aligned in all their aspects with the principles on which GoProForMED project is based, but they may contain some inspirational elements, which is why they have been reported in full.

The effectiveness of the proposed models will be validated through their experimental application in the demonstration areas (T4.2), located within the 4 target habitats present in the 12 project sites, namely

- 9260 *Castanea sativa* woods
- 9330 *Quercus suber* forests
- 9340 *Quercus ilex* and *Quercus rotundifolia* forests
- 9530* (Sub-) Mediterranean pine forests with endemic black pines

The silvicultural intervention models to be implemented are defined according to stand characteristics (young high forests, mature high forests, coppice) combined with different fertility conditions (low and medium/high).

The intervention models proposed here constitute a 'second level' of forest planning, which follows a 'first level' of planning. The first level of planning consists of the definition, identification and implementation of an ecological network, consisting of Core Areas, Biodiversity Islands and Habitat Trees, whose main objective is to preserve forest biodiversity, maintaining and/or improving a good conservation status of the target forest habitat.

On the other hand, the demonstration intervention models are aimed at the forest management of the 'matrix' (in the project defined as Edge Area) in which the ecological network is located, with the objective of proposing alternative and innovative forest management models, which can also take into consideration productive and economic aspects, without negatively affecting the conservation of forest biodiversity.

The demonstration areas are areas of one hectare, located in the 'Edge area' of the target forest habitat. The project envisages that the entire Edge Area can be managed by replicating the intervention models tested in the demonstration areas.

## 2. Introduction to *Closer-to-nature* forest management

In recent years, driven by the global biodiversity crisis and climate change, all the spotlight is on the need to find solutions and strategies to meet these challenges globally.
Forests, the conservation of their biodiversity and of their multiple functions, play a central role within this debate. As a result, forest management is receiving increasing attention. In recent years, numerous documents, guidelines and manuals have been written on the topic of sustainable forest management, on the adaptation of forests to climate change, on the conservation of biodiversity and their multiple ecosystem services[1,2,3,4,5].
Therefore, much of the information in this chapter is taken directly and *verbatim* from these authoritative sources, but with the intent of providing a clear and accurate picture of forest management approaches, some of which overlap, and have common goals.

A rich and varied portfolio of management approaches that aim to achieve the integration of all these aspects in forest production management has developed across Europe: *Closer-to-nature* forestry, 'Plenterwald', continuous cover forestry, reduced impact logging, retention forestry, tree-oriented silviculture, adaptive forest management, climate-smart forestry, etc, variety of forest management approaches that have been developed by practitioners across Europe[3].
Many of these trends are mutually compatible and can be considered simultaneously, as they are based more on guiding principles than on objective figures of silvo-dasometric indicators[6].
The basic premise of any form of silviculture is its adherence to a general model of sustainable forest management, that is: "a dynamic and evolving concept, which aims to maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations"[7].

In Europe, the Biodiversity Strategy for 2030[8] highlights the importance of sustainably managing forests as a nature-based solution in the fight against climate change, and it calls for biodiversity-friendly forestry practices to continue and to be further developed. To this end, it asks the Commission to develop guidelines on Closer-to-Nature Forest management (CNF)[9]. The EU Forest Strategy for 2030[10] echoes this commitment and defines closer-to-nature forest management as a set of practices to ensure multifunctional forests by combining biodiversity goals, carbon stock preservation and timber-related revenues.

**CNF** is a new concept proposed in the EU Forest Strategy for 2030, which aims to improve the conservation values and climate resilience of multifunctional, managed forests in Europe[11]. CNF, based on ecosystem dynamics, encompasses existing approaches oriented to increasing biodiversity in managed forests under the umbrella concept of sustainable forest management[5].

**Main objectives of CNF**

CNF serves as an accelerator for biodiversity restoration, biodiversity conservation and forest resilience to climate change based on two main objectives:

(i) increasing structural complexity; and

(ii) promoting natural forest dynamics.

**CNF concepts differ by country and region**. Overall, in north-east Europe, the concept of mimicking natural disturbances and maintaining natural structures (key habitats, deadwood, etc.) is prominent. In central and eastern Europe, CNF (the 'Pro Silva approach' and others) prevails, while in western Europe continuous-cover forestry (CCF) is mostly used.

As reported in the Guidelines, while forest management needs a region- and context-specific approach, building on Larsen et al. (2022)[11], the **general principles of CNF** are:

- learning from and permitting natural processes to develop;
- maintaining the heterogeneity and complexity of forest structures and patterns;
- integrating forest functions at different spatial scales;
- using a variety of silvicultural systems based on natural disturbance patterns of the region;
- low-impact timber harvesting with equal attention being paid to what is retained in the forest and what is removed, thus preserving habitats, forest soil and forest microclimates

Most of the existing guidelines for **forest management practices include**:

- natural regeneration;
- native species;
- local provenances;
- stands composed of trees of different ages;
- mixed stands composed of different tree species;
- landscape variation;
- careful tending and harvesting operations;
- balancing the pressure of ungulate populations;
- preserving the quantity and diversity of deadwood;
- preserving tree-related microhabitats;
- old groves;
- encouraging rare tree species; and
- preserving special key biotopes.

**MAIN FOREST MANAGEMENT APPROACHES**

***Closer-to-nature* forest management** aims to 'optimize maintenance, conservation, and utilisation of forest ecosystems in such a way that the ecological and socioeconomic functions are sustainable and profitable'[12]. Its main focus is single-tree selection harvesting based on a set of principles that can be translated to local conditions and challenges. Smaller group harvesting (< 0.2 ha) makes it possible to create 'mosaic' stands composed of a variety of tree species.

**Continuous cover forestry (CCF)** or uneven-aged management maintains a heterogenous forest structure within a stand, by periodically selecting and harvesting individual trees or groups of trees[13]. Clear-felling is preferably limited to 0.25-ha areas to ensure continuity of woodland conditions.

**Irregular silviculture** is one strand of CCF, which aims at permanently irregular high forest structures. It emphasizes natural processes and seeks to develop complex habitat structures with a range of different size-classes of trees and an understorey partly comprised of tree saplings [14].

**Retention forestry** aims to strengthen biodiversity considerations in even-aged management and clear-cutting systems. It can also be applied in CCF. Biodiversity and ecological function at different spatial scales are promoted by strengthening continuity in forest structure, composition and complexity[15]. Variable retention levels at landscape scale ensure structural diversity. The quality, diameter and age of tree species are important parameters.

**Tree-oriented silviculture** is based on targeted interventions aimed to advantage only some selected trees (target trees) and it makes possible focusing the efforts mainly on such aspects as the species mixture, stand structure, regeneration and intra/inter specific competition dynamics[16].

**Adaptive Forest Management (AFM)** aims to preserve and develop the functionality of specific forests as a prerequisite for fulfilling the future need for forest ecosystem services. This is dedicated to all measures that adapt intact forests to changing growth and management conditions due to environmental setting, but also, e.g., due to diverse economic perspectives AFM is based on three pillars: (1) knowledge of both environmental settings including uncertainties, but also of perception changes among decision-makers; (2) options to identify forest adaptive capacity, to protect forest performance and to apply AFM strategies; and (3) decisions to repeatedly optimize AFM according to significant evaluation outcomes[17].

**Climate-Smart Forestry (CSF)** is a targeted approach or strategy to increase the climate benefits from forests and the forest sector, in a way that creates synergies with other needs related to forests. The approach builds on three pillars: i) reducing and/or removing greenhouse gas emissions to mitigate climate change, ii) adapting forest management to build resilient forests, iii) active forest management aiming to sustainably increase productivity and provide all benefits that forests can provide[18].

# 3. *Closer-to-nature* forest management in the Mediterranean area

In this chapter we report *verbatim* what has already been analyzed in the chapter dedicated to the Mediterranean Biogeographical Region, taken from the document "Guidelines on *Closer-to-Nature* Forest Management"[19].

The current Mediterranean landscape is the result of a long-term interaction between forest ecosystems and human populations that developed over millennia, creating a biocultural diversity recognised by the EU.Forest in the Mediterranean region is part of a landscape mosaic with different land uses (agriculture, agroforestry, forestry and grazing) and different patches of vegetation type and vegetation structure.

There is a lack of a tradition of forest practice, including harvesting, in increasingly urban societies that lack a forest 'culture'. This makes it difficult to incorporate sustainable forest management. Forest value chains are not well developed locally in many European Mediterranean forests, so markets for forest products are also not well developed, limiting forest activity.

Even though there is significant variability within the CNF concept, some aspects are shared among all Mediterranean forest types and management approaches that implement CNF.

These aspects are set out in the bullet points below.

- Emphasis on increasing the retention of live and dead trees (single tree, group or patch retention) and coarse woody debris. Even though closer-to-nature forests in Mediterranean countries currently have a lower average amount of deadwood than other EU regions (linked to their predominantly young age and slow growth), there is a broad stakeholder recognition, supported by government and regional regulations, of the value of retaining deadwood. Therefore, the increment of deadwood has to be carefully evaluated site by site according to vulnerability to forest fires, vulnerability to drought and the need to prevent phytosanitary diseases.
- Progressive increase in the rate of mixed and naturally regenerated forests, even though: (i) most Mediterranean forests are regenerated naturally; and (ii) the rate of mixed forests in Mediterranean countries is generally high (except in plantations).
- Importance of increasing the presence of secondary tree species that could incorporate a lot of value to the forest stand, such as Sorbus sp., Prunus sp. or others.
- The role of natural disturbances with special reference to droughts and forest fires. Depending on the forest ecosystem, forest fires may play an essential ecological role in biodiversity conservation, but this role should be carefully managed to adopt an integrated approach to managing forest fires, including, in some locations, prescribed burning. Measures to adapt to fire disturbance in several southern European forest types rely on an ecological understanding of the species' fire ecology and on the specific effects of fire on the forest structure, soils and regeneration processes.
- The role of grazing in Mediterranean landscapes, by both domestic and wild animals, the need to allow managed grazing in forests, and the need for more dynamic management of deer and boars through hunting.
- Increasing the diversity of productions and types of crown covertures and species compositions to manage the production of non-wood forest products, particularly: cork, resin, nuts, berries, medicinal plants, truffles and wild mushrooms.

A variety of silvicultural systems have been applied in different Mediterranean regions for decades, bringing the benefits of predominantly mixed-stand composition. These systems include: mixed-stand silviculture; single-tree silviculture; irregular management; mixed regeneration; sporadic species valorisation and enhancement; and many others.

All these silvicultural systems, including new management rules for coppicing, show an emphasis on tree retention and are implemented to develop mixed and often multi-layered forests in line with CNF principles.

## 4. Demonstrative intervention models for target habitats

Traditional forest management in Mediterranean areas has historically relied on regular silvicultural models, such as even-aged high forests and simple coppices, which have led to the development of structurally homogeneous stands. In this context, the introduction of continuous cover forestry represents a paradigm shift. It not only changes the type of silvicultural intervention, but also entails a complete rethinking of management objectives.

However, this transition cannot occur abruptly, precisely because the simplified stands currently in place do not yet possess the necessary characteristics to support, for example, natural regeneration under cover or an uneven-aged structure. For this reason, the application of continuous cover forestry in Mediterranean contexts requires a gradual approach, consisting of progressive, targeted, and patient interventions.

The proposed interventions involve silvicultural treatments designed to guide the forest structure toward an irregular, continuous-cover system, characterized by the coexistence of trees of varying diameters and ages.

The **primary goal** of these interventions is to promote healthy, **resilient forest stands that can support enhanced multifunctionality and long-term ecological stability**.

Specifically, these interventions aim to:

- Ensure sustained timber production over time;
- Promote the production of high-quality wood and cork;
- Preserve biodiversity;
- Preserve landscape value;
- Ensure soil protection;
- Promote natural regeneration;
- Enhance the forest's capacity for carbon sequestration.

The interventions consist of **selective thinning**, carried out either on individual trees or small groups of trees.

The first step involves **identifying candidate trees** to be favored, to be selected on the base on the following characteristics:

- **High potential economic value**, i.e., individuals with well-shaped stems or high-quality cork, suitable for valuable timber or cork production;
- **Good vigor and stability**, with well-balanced crowns that contribute to the overall stability of the stand and to seed production;
- **High ecological value**, such as “habitat trees” as defined by the project.

Several useful tools are available for assessing economic value. In this context, two key references were used: the *“Protocol for Standing Timber Quality Assessment of Valuable Broadleaves”*, developed within the LIFE MixForChange project (LIFE15 CCA/ES/000060), which provides guidelines for evaluating the quality of standing timber; and, for cork quality assessment, the *“Field Guide to Cork Commercialization”*, developed by UNAC – União da Floresta Mediterrânica[20,21].

Once the candidate trees have been identified, the next step involves removing competing trees that interfere with their crown development, in order to ensure adequate space and resources for their growth. At the same time, trees that have reached the target diameter are felled, in accordance with silvicultural objectives and stand renewal strategies.

These are generally low to medium-intensity operations, involving no more than **25–30% of Basal Area**, and are intended to be repeated over time, typically every 7–15 years. To ensure their long-term operational and economic sustainability, the presence of a well-developed road network is essential, facilitating access to the forest.

This type of silviculture requires a preliminary phase of observation and analysis of the forest stands. Depending on the forest's initial condition, interventions should be tailored and adapted to the specific context, taking into account **6 key elements**: the Optimal Growing Stock, the Structure and successional stage, Stability, Regeneration, the Specific diversity and Biodiversity conservation.

1. The **Optimal Growing Stock (OGS)** is defined as a quantity of standing timber volume compatible with balanced management of an irregularly structured forest stand[28].
   Maintaining the OGS allows for:

   - optimized timber production,
   - favorable conditions for crown development and the growth of high-quality timber trees,
   - a stable ecosystem balance, which is essential for the proper functioning of organic matter mineralization processes,
   - effective natural forest regeneration.

   An excessive standing volume can hinder tree growth, reduce wood quality, and limit regeneration. On the other hand, overly low volume can encourage the spread of herbaceous and shrubby species, which compete with tree seedlings and inhibit natural regeneration. It also increases the risk of tree stress due to excessive light or water scarcity, ultimately compromising the overall stability of the forest stand.

   In the process of transforming even-aged stands into uneven-aged structures, the achievement of the equilibrium growing stock occurs gradually, through initially cautious interventions that become progressively more intensive. This step-by-step approach allows for the observation of improvements in ecosystem functioning over time, with particular focus on natural regeneration capacity, which is the first and most important indicator of successful management.

   The Optimal Growing Stock can be represented as a species-specific range of basal area (BA/ha). Maintaining this balance supports the correct ecosystem functioning also sustaining an effective natural regeneration process. The determination of the Optimal Growing Stock is influenced by several factors, including site exposure, soil fertility, latitude, and the structural characteristics of the forest stand.

   As an example, below are listed the Optimal Growing Stock, expressed in $m^2$/ha, for cork oak as defined in the *Guidelines for Sustainable Forest Management in Catalonia* (ORGEST), and for other species as outlined in the *Regional Forest Management Scheme* (*Schéma*

*Régional de Gestion Sylvicole* – SRGS), developed by the *Centre National de la Propriété Forestière* (CNPF):

Oaks, ashes: 12-16 $m^2$/ha

Cork: 18-22 $m^2$/ha (under cork)

Beech, Chestnut, Maple: 17-22 $m^2$/ha

Pine, larch, cedar: 20-30 $m^2$/ha

Spruce, Douglas fir: 25-35 $m^2$/ha

These values refer to trees with DBH > 17,5 cm. Trees belonging to the 'Saplings' category (7,5 < DBH < 17,5) should account for an additional 2-3 $m^2$/ha.

| AB > OGS | AB = OGS | AB < OGS |
|---|---|---|
| Dense stand, competition between individuals too high.<br><br>Gradually reduce growing stock through frequent, low to medium-intensity thinning, taking out more than the annual growth rate.<br>It is recommended not to remove more than 25% of the volume to maintain stand stability. | The stand conditions are ideal for enhancing the quality of the growing stock.<br><br>Perform moderate-intensity thinning (removing 15-20% of the volume) to maintain the stand within the optimal range.<br><br>Favour high quality trees to promote their growth. | The stand is too open, promoting undergrowth dynamics.<br><br>It is advisable to wait for an increase in density before intervening.<br><br>Low-intensity thinnings could be carried out only in the densest areas. |

2. **Structure and stage of development**: the vertical and horizontal structure, along with the developmental stage of a forest, are key factors to consider when determining the type and intensity of intervention. In the case of young or adult even-aged stands, the goal should not be to immediately shift the structure from regular to irregular. Instead, it's important to recognize that the process of creating an irregular structure is gradual, requiring a series of carefully planned interventions.

   Several indices are available for assessing structural diversity. In this case, it was decided to refer to the TDD and THD (Tree Diameter Diversity Index and Tree Height Diversity Index), which provide a quick and effective way to quantify the dimensional variation of trees and the vertical structure of the forest stand.

   Both indices are derived from the modified formula of the Shannon-Wiener index[24,25,27]:

$$TDD; THD = -\sum_{i=1}^{n} (pi * \ln(pi))$$

Where *pi* represents the number of trees belonging to the i-th class and *n* the number of classes, with a pitch of 5 cm for diameter and 2 m for height.

These indices **range from 0 to a theoretical maximum**, calculated as *ln(n)*. Values near 0 indicate a stand with trees of similar diameter or height, whereas values approaching the theoretical maximum reflect a high degree of variability.

For Mediterranean areas, the available literature provides few reference values. Therefore, in this context, the index is not used to compare different stands, but rather as a tool to assess the impact of a specific intervention on a given stand by comparing post-treatment conditions with the initial state.

| IRREGULAR STRUCTURE | REGULAR STRUCTURE | REGULAR STRUCTURE |
|---|---|---|
| Maintain structural diversity and, when possible, favour specific diversity.<br>Remove trees that have reached the target diameter and promote those of better quality | (consisting mainly of Poles and Large categories)<br>The process of creating an irregular stand structure will require multiple interventions.<br>Favour specific diversity and high-quality trees while preserving younger, dominated trees. | (consisting mainly of Large and Very Large categories)<br>Guide the stand toward regeneration phases.<br>Gradually remove individuals that have reached the target diameter. |

3. **Stability**: a stable forest is more resilient to environmental stresses, reducing the risk of degradation or system collapse. This stability helps ensure the forest can continue to fulfil its ecological functions and provide essential resources such as timber, water, and clean air.

   The stability of a forest stand can be assessed using the slenderness coefficient, given by the ratio between average height and diameter. The higher the coefficient values (greater than 100), the more unstable the stand is considered to be. In a stand represented by a high ratio, it is necessary to carefully evaluate the actual feasibility of interventions, as these could lead to increased instability within the stand.

| STABLE FOREST STAND | MODERATELY STABLE FOREST STAND | UNSTABLE FOREST STAND |
|---|---|---|
| Hm/Dm < 80<br>Medium-intensity thinnings (20-25% of the volume) can be carried out.<br>Maintain trees that contribute to forest stability. | Hm/Dm < 100<br>In order not to further compromise stand stability, it is advisable to adopt a lower thinning intensity of 15-20 % of the volume.<br>Maintain trees that contribute to forest stability. | Hm/Dm > 100<br>Minimize intervention intensity as much as possible while increasing their frequency. |

4. **Regeneration**: observing forest regeneration—including its presence or absence, species composition, and overall vigour—provides insight into ongoing ecological dynamics. This helps identify limiting factors and the degree of disturbance, such as overly dense stands, overgrazing, or excessive herbaceous and shrub cover. Such observations are essential for guiding appropriate management actions to support the proper functioning and long-term health of the forest ecosystem.

| ABSENT (YOUNG OR ADULT FOREST) | ABSENT (MATURE FOREST) | PRESENT |
|---|---|---|
| Regeneration is not currently necessary.<br>Interventions are aimed at improving the present growing stock. | Identify the limiting factor:<br>LIGHT: gradually reduce stand density to allow the initiation of the regeneration process.<br>DIRECT COMPETITION with undergrowth: carry out clearing of the undergrowth.<br>GRAZING: Protect existing seedlings. | Assess the conditions that promote natural regeneration, with the goal of replicating and enhancing them through targeted interventions in future management actions. |

5. **Species diversity**: a careful analysis of the current vegetation is of great importance in order to understand the ecological and successional dynamics of the forest and consequently adopt appropriate management choices[23]. This includes identifying which trees should be promoted or removed to enhance stand structure and achieve an optimal balance between growth, productivity, and conservation. In general, the presence of multiple tree species within a stand is crucial for maintaining or enhancing biodiversity, ensuring that the ecosystem remains resilient, healthy, and functional—even in the face of climate change and natural disturbances.

There are several indices that can provide useful information on the specific diversity of a stand, in order to support management choices.

Among these, the Pielou index, also known as the ***Eveness* index**, expresses how equally distributed (or not) the individuals in a community are among the different species that compose it. In other words, it measures the relative abundance of the different species in the same area.

The index is the ratio between the Shannon-Wiener index and its maximum value for that community and is therefore calculated as follows:

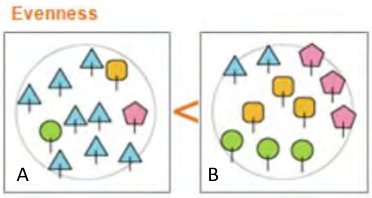


*Figure 1. Graphs A and B display the same species richness. However, Graph B shows a more even distribution of individuals among species, resulting in a higher evenness index compared to Graph A.*

$$EVENESS = \frac{-\sum(pj * \ln(pj))}{\ln(S)}$$

Where $pj$ represents the number of individuals per species ($n$) and $S$ represents the number of species present.

The index **ranges from 0 to 1**. The more individuals are concentrated in one or a few species, the lower the index value. Conversely, the more individuals are similarly distributed among the species, the higher the value.

EVENESS > 0,8

The species are evenly distributed.

Maintain the current conditions unless they pose a problem for other factors (eg. Overtaking of primary species by secondary species)

0,5 < EVENESS < 0,8

The species are fairly evenly distributed.

Be careful not to remove less represented species.

EVENESS < 0,5

The stand is dominated by one or a few species.

Preserve the less represented species.

Promote the most vigorous individuals belonging to these species.

6. **Biodiversity conservation:** integrating biodiversity conservation into productive forest management is essential for maintaining ecological balance and ensuring the long-term functionality of forest ecosystems. A biodiversity-integrated approach not only safeguards species and habitats but also enhances the forest's resilience to climate change and other environmental stresses. By promoting greater stability and productivity, this type of management supports the sustainable use of forest resources without compromising environmental health.

To evaluate key aspects of forest biodiversity, the Index of Biodiversity Potential[26] is used, as briefly described in BOX – 1.

# BOX 1 – FATTORI IBP E LORO VALUTAZIONE

Below are the 10 IBP factors: the first 7 can be influenced through forest management, while the remaining 3 depend on site-specific characteristics. Each factor is assigned a value of 0, 1, 2, or 5.
On the right, the conditions required to assign the maximum score for each factor within the Mediterranean biogeographical region are listed.
The Management IBP can range from 0 to 35, while the Context IBP can range from a minimum of 0 to a maximum of 15.

| | | |
|---|---|---|
| Management factors | A- Native species | At least 5 *genera* |
| | B – Vertical structure | Presence of 5 vertical layers<br>(with leaves covering at least 20 % of the surface)<br>• herbaceous and semi-ligneous<br>For woody species<br>• Very low (<1,5 m)<br>• Low (1,5 to 7 m)<br>• Intermediate (7 to 15 m)<br>• High (>15 m) |
| | C – Standing deadwood | At least 3 trunks/ha with DBH > 27,5 cm |
| | D – Laying deadwood | At least 3 trunks/ha with DBH > 27,5 cm |
| | E – Large living trees | At least 5 trees/ha with DBH > 57,5 cm |
| | F – Living trees with microhabitats | At least 8 trees/ha with microhabitats of at least 4 different categories |
| | G – Open habitats | Forest gap or clearing between 1 and 5% of the described stand |
| Context factors | H – Forest continuity over time | ancient forest (on forest map since 1936) |
| | I – Aquatic habitats | At least 2 types<br>(streams, lakes, ponds, springs…) |
| | J – Rocky habitats | At least 2 types<br>(Pile of boulders, cliffs, large rocks…) |

**IBP MANAGEMENT > 28**

Ensure the maintenance of key elements.

**IBP MANAGEMENT 14 TO 28**

Ensure the maintenance of key elements and implement punctual interventions to improve deficient factors.

**IBP MANAGEMENT < 14**

YOUNG STAND: Ensure the maintenance of the largest trees.

ADULT STAND: plan targeted interventions to improve limiting factors.

## 5. Summary sheets of interventions for the 4 target habitats

<table>
<tr><th colspan="2">Habitat 9260 – Boschi di Castanea sativa — Source: 28, 33</th></tr>
<tr><td colspan="2">Objective: high-quality wood production and biodiversity conservation</td></tr>
<tr><td>Silvicultural treatment<br><br>The interventions consist of identifying candidate trees to be favoured through selective thinning, either on individual stems or groups of trees. For each candidate tree, the number of surrounding trees to be removed may range from 1 to 3.<br>Specifically, it is recommended to:<br><br>• Identify 100–200 candidate trees/ha, or in any case no more than one-quarter of the total number of individuals, selecting trees with good vigour and stability, well-formed crowns, preferably among chestnut trees (if healthy and vigorous individuals are present) or other broadleaved species, ideally with good potential for high-quality timber production.<br><br>• Ensure the presence of at least 3 habitat trees/ha or potential habitat trees.<br><br>• Ensure the presence of at least 5 trees/ha designated for unrestricted growth, in order to support long-term structural diversity and enhance the ecological value of the stand.<br><br>• Retain suppressed trees to promote the development of a vertically irregular structure, aiming to achieve the presence of 2–3 distinct diameter classes within the stand over time.<br><br>• Gradually harvest high-quality individuals that have reached the target diameter, ranging between 40 and 65 cm.<br><br>• Assess the opportunity to create small canopy gaps, ensuring they are not placed near individuals of invasive alien species (e.g., Robinia pseudoacacia, Ailanthus altissima) to minimize the risk of their spread.<br><br>• Where present, preserve fruit-producing chestnut trees (dead or alive) from the previous cultivation cycle of the chestnut orchard.<br><br>• In adult or mature stands, plan to fell and leave on the ground 3 trees/ha, and to ring-bark (girdle) an additional 3 trees/ha, each with a minimum DBH of 17.5 cm. This aims to enhance both the quantity and diversity of deadwood, in various stages of decomposition, both standing and lying.</td>
<td>Intervention intensity<br>*Percentages referring to the Basal Area subject to the intervention<br><br>G> OGS (17-22 m2/ha)<br><br>20-30%*<br>Gradually reduce the basal area in order to maintain the bioecological and physical stability of the forest. This may involve planning more frequent interventions, starting with low-intensity actions that progressively increase in intensity until the equilibrium condition is achieved.<br><br>G≤ OGS (17-22 m2/ha)<br><br>Plan interventions to maintain the growing stock within the recommended range. This may also mean postponing the intervention to the next cycle if necessary.</td></tr>
<tr><td colspan="2">Rotation period: Ranging between 10–15 years. In the case of interventions aimed at transforming even-aged stands into uneven-aged ones, the return interval should be assessed on a case-by-case basis.</td></tr>
</table>

<table>
<tr><th colspan="2">Habitat 9340 – Quercus ilex and Quercus rotundifolia forests — Source: 6, 28, 30</th></tr>
<tr><td colspan="2">Objective: high-quality wood production and biodiversity conservation</td></tr>
<tr><td>Silvicultural treatment<br><br>The interventions consist of identifying elite trees to be favoured through selective thinning, either on individual stems or groups of trees. For each elite tree, the number of surrounding trees to be removed may range from 1 to 3. Specifically, it is recommended to:<br><br>• Identify 150–300 elite trees/ha, or in any case no more than one-third of the total number of individuals, selecting those with good vigor and stability, well-formed crowns, and distributed across all represented diameter classes, selected among individuals of holm oak and other broadleaved species (where present), ideally with good potential for high-quality timber production.<br><br>• Ensure the presence of at least 3 habitat trees/ha or potential habitat trees.<br><br>• Ensure the presence of at least 5 trees/ha designated for unrestricted growth, in order to support long-term structural diversity and enhance the ecological value of the stand.<br><br>• Retain suppressed trees to promote the development of a vertically irregular structure, aiming to achieve the presence of 2–3 distinct diameter classes within the stand over time.<br><br>• Gradually harvest high-quality individuals that have reached the target diameter of 30 cm.<br><br>• Encourage the presence of other species and the initiation of natural regeneration processes where suitable conditions exist (see Criterion 4).<br><br>• In dense stands, plan the creation of small canopy openings ranging from 100 to 500 m².<br><br>• In adult or mature stands, plan to fell and leave on the ground 3 trees/ha, and to ring-bark (girdle) an additional 3 trees/ha, each with a minimum DBH of 17.5 cm. This aims to enhance both the quantity and diversity of deadwood, in various stages of decomposition, both standing and lying.</td>
<td>Intervention intensity<br>*Percentages referring to the Basal Area subject to the intervention<br><br>G> OGS (12-16 m2/ha)<br><br>15-25%*<br>Gradually reduce the basal area in order to maintain the bioecological and physical stability of the forest. This may involve planning more frequent interventions, starting with low-intensity actions that progressively increase in intensity until the equilibrium condition is achieved.<br><br>G≤ OGS (12-16 m2/ha)<br><br>Plan interventions to maintain the growing stock within the recommended range. This may also mean postponing the intervention to the next cycle if necessary.</td></tr>
<tr><td colspan="2">Rotation period: Ranging between 7–15 years. In the case of interventions aimed at transforming even-aged stands into uneven-aged ones, the return interval should be assessed on a case-by-case basis.</td></tr>
</table>

## Habitat 9330 – Quercus suber forests

*Source: 22, 28, 29*

**Objective:** production of high-quality cork and biodiversity conservation

### Silvicultural treatment

In cork oak stands, two main diameter classes under cork can be distinguished: the first, ranging from 10 to 30 cm, includes individuals suitable for selective thinning—either individually or in groups—aimed at promoting their growth; the second class, ranging from 30 to 50 cm, includes individuals that have reached their peak productive potential.

The interventions consist of identifying elite trees to be favoured through **selective thinning**, either on individual stems or groups of trees. For each elite tree, the number of surrounding trees to be removed may range from 1 to 3.

Specifically, it is recommended to:

- **Identify 150–300 elite trees/ha** r in any case no more than one-third of the total number of individuals. Candidate trees should be selected among cork oaks with a diameter under bark of at least 10 cm. They should also be vigorous and stable individuals, with well-formed crowns and, ideally, good potential for high-quality cork production.
- Ensure the presence of **at least 3 habitat trees/ha** or potential habitat trees.
- Ensure the presence of **at least 5 trees/ha** designated for unrestricted growth, in order to support long-term structural diversity and enhance the ecological value of the stand.
- Ensure the **presence of 2–3 distinct diameter** classes within the stand, aiming for a structure in which approximately 50% of the basal area is made up of trees within the productive diameter class (30–50 cm)
- Gradually harvest high-quality individuals that have reached **the target diameter of 60 cm** above cork which generally corresponds to the point at which cork production is no longer economically viable.
- Adjust the species composition to favor cork oak, aiming for it to account for at least 60% of the total number of individual. At the same time**, encourage the presence of secondary species** to increase overall diversity, while maintaining cork oak as the dominant species in the stand.
- Carry out interventions to **reduce the shrub layer** to around 30% coverage, removing the most flammable species.
- Ensure a **canopy cover between 60% and 80%**, which represents the ideal condition for allowing sufficient light to trigger natural regeneration processes, support their establishment, and improve both the overall vitality of the forest and the quality of the cork-producing trees.
- In adult or mature stands, plan to fell and **leave on the ground 3 trees/ha**, and to **ring-bark (girdle) an additional 3 trees/ha**, each with a minimum DBH of 17.5 cm. This aims to enhance both the quantity and diversity of deadwood, in various stages of decomposition, both standing and lying.

### Intervention intensity

*Percentages referring to the Basal Area subject to the intervention

**G> OGS (18-22 m2/ha)**
**Young stands**

**20-25%***

Regulate competition among individuals and promote trees with greater vitality and better potential for high-quality cork production by encouraging their dimensional growth, while removing those with low productive potential, such as malformed or damaged individuals.

Maintain the final canopy cover of the stand between 60% and 80%.

**G≤ OGS (18-22 m2/ha)**
**Adult stands**

**15-20%**

Regulate competition among individuals by favoring trees with greater vitality and better potential for high-quality cork production, through the removal of declining trees or those with low productive potential.

Gradually remove trees that have reached the harvestable diameter of 60 cm over bark.

Promote natural regeneration and, where conditions are not suitable, plan group-based interventions to encourage vegetative regeneration as a supplement to natural regeneration.

**G≤ OGS (18-22 m2/ha)**
**forest cover <60%**

Plan interventions to maintain the growing stock within the recommended range. This may also mean postponing the intervention to the next cycle if necessary.

**Rotation period:** Ranging between 7–15 years. In the case of interventions aimed at transforming even-aged stands into uneven-aged ones, the return interval should be assessed on a case-by-case basis.

## Habitat 9340 – *Quercus ilex* and *Quercus rotundifolia* forests

*Source: 28, 31, 32*

**Objective:** production of high-quality timber and biodiversity conservation

**Silvicultural treatment**

The interventions consist of identifying elite trees to be favoured through **selective thinning**, either on individual stems or groups of trees. For each elite tree, the number of surrounding trees to be removed may range from 1 to 3. Specifically, it is recommended to:

- **Identify 100 elite trees/ha**, with an average spacing of 10 meters between them. Selected trees should be vigorous and stable (preferably with a height-to-diameter ratio < 90), with a deep and symmetrical crown. Elite trees may also include individuals of other species, if present, and should ideally have potential for high-quality timber production.
- Ensure the presence of **at least 3 habitat trees/ha** or potential habitat trees.
- Ensure the presence of **at least 5 trees/ha** designated for unrestricted growth, in order to support long-term structural diversity and enhance the ecological value of the stand.
- Retain suppressed trees to promote the development of a vertically irregular structure, aiming to achieve the **presence of 2–3 distinct diameter classes** within the stand over time.
- Gradually harvest high-quality individuals that have reached **the target diameter of 50 cm.**
- Encourage the presence of other species and the initiation of natural regeneration processes where suitable conditions exist (see *Criterion 4*).
- In dense stands, plan the creation of small canopy openings fo a surface of maximum 1000 $m^2$.
- In adult or mature stands, plan to fell and **leave on the ground 3 trees/ha**, and to **ring-bark (girdle) an additional 3 trees/ha**, each with a minimum DBH of 17.5 cm. This aims to enhance both the quantity and diversity of deadwood, in various stages of decomposition, both standing and lying.

**Intervention intensity**
*Percentages referring to the Basal Area subject to the intervention

**G> OGS (20-30 m2/ha)**
**Hm/Dm < 80**

**20-25%**
Gradually reduce the basal area in order to maintain the bioecological and physical stability of the forest. This may involve planning more frequent interventions, starting with low-intensity actions that progressively increase in intensity until the equilibrium condition is achieved.

**G> OGS (20-30 m2/ha)**
**Hm/Dm >80**

**15-20%**
Reduce the basal area through cautious, low-intensity interventions, retaining the most stable trees in the stand even if they have limited economic value.

**G≤ OGS (20-30 m2/ha)**

Plan interventions to maintain the growing stock within the recommended range. This may also mean postponing the intervention to the next cycle if necessary.

**Rotation period:** Ranging between 10–15 years. In the case of interventions aimed at transforming even-aged stands into uneven-aged ones, the return interval should be assessed on a case-by-case basis.

# 6. Bibliography


1. Pro Silva Principle, 2012. 68 pp.
2. Kraus D., Krumm F. (eds) 2013. Integrative approaches as an opportunity for the conservation of forest biodiversity. European Forest Institute. 284 pp.
3. Krumm F, Rigling A, Bollmann K, Brang P, Dürr C, Gessler A, Schuck A, Schulz-Marty T, Winkel G. 2020. Synthesis: improving biodiversity conservation in European managed forests needs pragmatic, courageous, and regionally-rooted management approaches. In: Krumm F, Schuck A, Rigling A (eds). How to balance forestry and biodiversity conservation – A view across Europe. European Forest Institute (EFI); Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Birmensdorf. Pp. 609–633.
4. Larsen, J.B., Angelstam, P., Bauhus, J., Carvalho, J.F., Diaci, J., Dobrowolska, D., Gazda, A., Gustafsson, L., Krumm, F., Knoke, T., Konczal, A., Kuuluvainen, T., Mason, B., Motta, R., Pötzelsberger, E., Rigling, A., Schuck, A., 2022. Closer-to-Nature Forest Management. From Science to Policy 12. European Forest Institute. https://doi.org/10.36333/fs12
5. Brussels, 27.7.2023 SWD (2023) 284 final - Guidelines on Closer-to-Nature Forest Management
6. Coello J, Piqué M, Beltrán M, Coll L, Palero N, Guitart L. 2022. Adaptive and close-to-nature management in mixed sub-humid Mediterranean forests: holm oak, chestnut, common oak and pine woods. Forest Science and Technology Centre of Catalonia, Solsona (Lleida, Spain); Forest Ownership Centre, Santa Perpètua de Mogoda (Barcelona, Spain). 104 p.
7. FAO, 2022. Sustainable Forest Management. Sustainable forest management | FAO | Food and Agriculture Organization of the United Nations/. Accessed: 29/07/2024
8. EUR-Lex - 52020DC0380 - EN - EUR-Lex (europa.eu)
9. Brussels, 27.7.2023 SWD(2023) 284 final - Guidelines on Closer-to-Nature Forest Management
10. EUR-Lex - 52021DC0572 - EN - EUR-Lex (europa.eu)
11. Larsen, J.B., Angelstam, P., Bauhus, J., Carvalho, J.F., Diaci, J., Dobrowolska, D., Gazda, A., Gustafsson, L., Krumm, F., Knoke, T., Konczal, A., Kuuluvainen, T., Mason, B., Motta, R., Pötzelsberger, E., Rigling, A., Schuck, A., 2022. Closer-to-Nature Forest
12. Pro Silva, 2012. Pro Silva Principles. https://www.prosilva.org/close-to-nature-forestry/pro-silva-principles/
13. Gustafsson, L. et al, 2020. Retention as an integrated biodiversity conservation approach for continuous-cover forestry in Europe. Ambio, 49, 85-97. https://doi.org/10.1007/s13280-019-01190-1
14. Alder DC, Poore A, Norrey J, Newson SE, Marsden SJ, 2021. Irregular silviculture positively influences multiple bat Species in a lowland temperate broadleaf woodland, Forest Ecology and Management, Volume 483, 118786, ISSN 0378-1127, https://doi.org/10.1016/j.foreco.2020.118786.
15. Kraus D., & Krumm F. (Eds) (2013). Integrative approaches as an opportunity for the conservation of forest biodiversity. European Forest Institute; Krumm, F. et al. (Eds) (2020). How to balance forestry and biodiversity conservation – A view across Europe. European Forest Institute and Swiss Federal Institute for Forest, Snow and Landscape Research.
16. Mori P., Pelleri F. (eds), 2014. Silviculture for sporadic tree species. Extended summary of the technical manual for tree-oriented silviculture proposed by the LIFE+ project and PProSpoT. 34 pp.
17. Spathelf, P., Stanturf, J., Kleine, M. et al., 2018. Adaptive measures: integrating adaptive forest management and forest landscape restoration. Annals of Forest Science 75, 55. https://doi.org/10.1007/s13595-018-0736-4
18. Nabuurs G, Verkerk PJ, Schelhaas M, González Olabarria JR, Trasobares A, Cienciala E, 2018. Climate-Smart Forestry: mitigation impacts in three European regions. From Science to Policy 6. European Forest Institute.

19. Brussels, 27.7.2023 SWD(2023) 284 final - Guidelines on Closer-to-Nature Forest Management
20. Coello, Jaime & Garcia, Q & Baiges, Teresa. (2020). Protocol for standing timber quality assessment of valuable broadleaves.
21. UNAC - Mediterranean Forest Union, 2021. Cork Commercialization Guide. 2nd edition.
22. Vericat, P.; Beltrán, M.; Piqué, M.; Cervera, T. 2013. Models de gestió per als boscos de surera: producció de suro i prevenció d'incendis forestals. Sèrie: Orientacions de gestió forestal sostenible per a Catalunya (ORGEST). Centre de la Propietat Forestal. Departament d'Agricultura, Ramaderia, Pesca, Alimentació i Medi Natural. Generalitat de Catalunya.
23. Giacanelli V., 2005. L'importanza dell'approccio fitosociologico nel risanamento ambientale. In: Onori L., Di Noi A., Siniscalco C. (eds.), La rinaturalizzazione e il risanamento dell'ambiente per la conservazione della Biodiversità. Rapporti APAT 63/2005
24. Kuuluvainen, T., Penttinen, A., Leinonen, K., & Nygren, M. (1996). Statistical opportunities for comparing stand structural heterogeneity in managed and primeval forests: An example from boreal spruce forest in southern Finland. Silva Fennica. https://doi.org/10.14214/sf.a9243
25. Rouvinen, S., & Kuuluvainen, T. (2005). Tree diameter distributions in natural and managed old Pinussylvestris-dominated forests. Forest Ecology and Management. https://doi.org/10.1016/j.foreco.2004.11.021
26. Larrieu L., Gonin P.: 2008 - L'indice de Biodiversité Potentielle (IBP): une méthode simple et rapide pour évaluer la biodiversité potentielle des peuplements forestiers. Rev. For. Fr. 06-2008, p. 727-748
27. Dong-June & Kim, Ji. (2011). Comparative evaluation of species diversity indices in the natural deciduous forest of Mt. Jeombong. Forest Science and Technology. 7. 10.1080/21580103.2011.573940.
28. Centre National de la Propriété Forestière (CNPF), 2021. Schéma régional de gestion sylvicole d'Occitanie. https://www.calameo.com/books/0074117971004cbe0f363
29. Dettori Sandro et al. (2002) Sughericoltura. Note Tecniche Ersat.
30. Bec, Raphaël & Baudriller-Cacaud, Haïmad & Brusten, Thomas & Fanget, Gisèle & Galinat, Florian & Guibal, Frédéric & Limousin, Jean-Marc. (2021). Le chêne vert : nouvelles approches de gestion en contexte méditerranéen.
31. Bettini, Gianni & Bianchetto, Elisa & Butti, Fabrizio & Cantiani, Paolo & Chiellini, Carolina & De Meo, Isabella & D'Errico, Giada & Fabiani, Arturo & Gardin, Lorenzo & Graziani, Anna & Landi, Silvia & Marchi, Maurizio & Mazza, Giuseppe & Mocali, Stefano & Montini, Piergiuseppe & Plutino, Manuela & Roversi, Pio & Elena, Salerni & Samaden, Stefano & Torrini, Giulia. (2016). IL DIRADAMENTO SELETTIVO Accrescere stabilità e biodiversità in boschi artificiali di pino nero.
32. Beltrán Barba, Mario & Vericat, Pau & Pique, Miriam & Cervera, Teresa. (2012). Models de gestió per als boscos de pinassa ( Pinus nigra Arn.): producció de fusta i prevenció d'incendis forestals. Sèrie: Orientacions de gestió forestal sostenible per a Catalunya (ORGEST).
33. Farriol, Ricard & Beltrán Barba, Mario & Argemí, Josep & Bosch, Albert. (2014). Models de gestió per als boscos de castanyer. Aplicació pràctica de les ORGEST per a la producció de fusta i fruit en finques del Montseny.

# 7. Annex 1 - Best practices and experiences on *Closer-to-nature* forest management for the target forest habitats

In this annex we present a collection of 19 examples of good practices that adhere to the *Closer-to-nature* principles reported in the previous section, applied and tested in different forest contexts within the Mediterranean Biogeographic Region.

The selection of the case studies was made taking into account the Mediterranean geographic scope, the target forest formations (as much as possible related to the four target forest habitats), and the approaches applied, which in some cases may not be related to the project habitats, but describe techniques that in general can be applied to different forest formations.

As already mentioned in the introduction, some of the experiences described are not aligned in all their aspects with the principles on which GoProForMED project is based, but they may contain some inspirational elements, which is why they have been reported in full.

Summarized versions are provided in this document. Good practices are also included in the LIFE GoProFoR project database (LIFE17 IT/GIE/000561). For further details, please refer to the accompanying documentation.

The case studies are described adhering as closely as possible to the following general outline:

- Title of the good practice(Country - title)
- Project reference (Title, summary, website link)
- Description of the context of application of the good practice (Geographical location, territorial context, traditional management form)
- Target habitat or forest formation
- Description of the good practice (objectives, pressures/threats, case study description)
- Reference documentation for description of the good practice

# 1. CHESTNUTS - habitat 9260 Castanea sativa woods

## 1.1. Italy - Demonstration forests of Pro Silva Italia: chestnuts of Monte Amiata

**Project**: Demonstration forests of Pro Silva Italia

**In brief**: The project consists of a selection of Italian forests considered to be particularly significant for expressing the management approach proposed by PRO SILVA, in situations that are also very different in terms of status, climate and social economy. The demonstration forests identified so far by Pro Silva Italia are located at Col de Joux (Val d'Aosta); Podere Seradino (Umbria); Bosco delle Sorti della Partecipanza (Piedmont); Forests managed by the Consorzio Forestale Alta Valle Susa (Piedmont); Chestnut groves of Monte Amiata (Tuscany); Beech forests of Monte Amiata (Tuscany).

**Website**: https://www.prosilva.it/foreste-dimostrative

**Location:** Monte Amiata (Tuscany region)

**Territorial context**: Monte Amiata is an area of particular importance from a forestry point of view, located in a Mediterranean context, close to the coastal area of Tuscany, characterised by the presence of an isolated volcanic relief that reaches an altitude of 1738 m above sea level. Monte Amiata is characterised by three different vegetation belts: the basal part is characterised by a clayey substratum covered by coppices of oaks (mainly turkey oaks and hornbeams) with sporadic tree species. In the middle band, the trachytic substrate (700 to 1000 m above sea level) is covered by chestnut woods, mainly coppice on the eastern slope and seed woods on the western slope. Above 1000 m up to the summit, beech forests prevail. In the intermediate belt between chestnut and beech, there are numerous reforestations of conifers (pine, spruce, fir and larch).

**Traditional type of management**: coppice. Traditional management of chestnut coppices involved a 24-year rotation, with thinning at 12-15 years and the release of 60 standard treess per hectare. Recently, in 2003, new regulations for the Tuscan region reduced the number of standard treeses to 30 per hectare. Generally, these coppices are managed with frequent thinnings from below, applying the silvicultural stand approach.

**Forest habitat or forest type**: chestnut

**Aims**: to demonstrate, by means of a concrete example, the applicability of Pro Silva principles and chestnut coppice treatment methodologies to the Apennine realities as well, allowing a better enhancement of the naturalistic and productive qualities of chestnut coppices.

**Pressures/threats**: In the recent past, intensive mining activities in the area have interfered with forest conditions. Following the decline in the cultivation of chestnut trees, which began around 1950 and was caused by plant diseases and the abandonment of the rural area, most of the fruit chestnut groves were converted to coppice. This activity was economically viable due to the high demand for poles needed for mining activities. The presence of the mercury mines made it possible to maintain the rural population in the area and to absorb the assortment obtained from the coppices.

Subsequently, the mining crisis led to the discontinuation of coppicing and the launch of new forestry policies oriented towards forest conservation and the valorisation of wood products through management based on the lengthening of the shift and the application of thinnings.



Coordinator Partners Affiliated entities

**Case Study Description**: the 'Monte Amiata Chestnut Grove' demonstration forest was established as an example of silvicultural interventions carried out using an approach consistent with Pro Silva principles.

Within the Amiata demonstration forest, two different silvicultural models have been defined:

a) coppices with a 30-year rotation undergoing 3-5 thinnings;

b) coppices with a 50-year rotation undergoing 5-8 thinnings.

The current plan has provided for a forest area of 93 ha for long rotation coppice chestnut groves (shift of 50). As far as the release of trees with indefinite growth and/or dead trees in the forest is concerned, the indications provided by the Forestry Regulations of the Region of Tuscany are followed.

In 2008, in the locality of Sant'Antonio in an 11-year-old chestnut coppice, the approaches of stand silviculture (SS), tree-oriented silviculture (TS) and control (C) were compared. In the tree-oriented silviculture (TS) approach, thinnings were applied from above around a small number of target trees (100 per hectare), preserving the remaining part of the stand.

In 2017, after 2 thinnings carried out with the SS option and 3 thinnings with the TS option, the target trees selected with tree-oriented silviculture (TS) had higher growth than the target trees selected with the same criteria in the plots managed with the stand silviculture approach and in the control plot.

In 2017, the target trees had reached an average diameter of 22.1 cm, 16.2 cm and 14.4 cm in the TS, SS and C plots, respectively. This increased growth allows for a reduction in the time needed to obtain large valuable assortments.

Furthermore, the trunk quality of the target trees managed with TS appears to be higher than the target trees of the plots managed with the other silvicultural options.

The tree-based approach (TS), with thinnings from above around a small number of target trees (100/ha), preserving the rest of the stand was the best approach. The silvicultural intervention demonstrated while involving the coppicing of part of the stand allows the maintenance of a continuous cover for long periods and therefore soil fertility. However, no indications have been reported on the release of indefinitely growing trees or dead wood. The silvicultural intervention demonstrated, even though it involves the coppicing of part of the stand, makes it possible to maintain a continuous cover for long periods and to guarantee its achievement in a very short time (one or two growing seasons) compared to the rotation (30-50 years). Through the lengthening of the shift and the articulation of the vertical structure and texture, and thanks to the observed incremental effect, it implies both a positive effect on carbon uptake and increased litter production, and thus also has a beneficial effect on the soil and its biodiversity. Natural regeneration was not one of the current objectives of the intervention, but it is assumed that this intervention may allow natural regeneration of the forest in the future by gamic.

**Reference document**: "Le foreste dimostrative di PRO SILVA ITALIA. Scheda 05, Castagneti del Monte Amiata" (language: Italian)

## 1.2. Italy - Guidelines for silviculture of chestnut coppices

**Project**: National Rural Network Plan (PRRN) (2014-2022).

**In brief**: the RRN Plan has envisaged an 'activity sheet' entirely dedicated to forestry issues (Sheet no. 22 - Forests); specifically, with sub-sheet Forests 22.2.1 - Sustainable improvement of national forestry production, actions have been implemented for the comparison between the main stakeholders (through Focus Groups and thematic Workshops) and for the transfer of knowledge and innovation. The document described herein is part of this context and provides guidelines, mainly of a technical applicative nature, of quick and easy consultation, addressed to all those operating in the silviculture and rural development sector with particular attention to the main stakeholders of the sector and the supply chain

**Website**: NATIONAL RURAL NETWORK PROGRAM 2014-2022

**Location:** Italian territory

**Territorial context**: the main Italian chestnut-growing regions (i.e. Piedmont, Tuscany, Liguria, Lombardy, Calabria, Campania, Emilia Romagna, Lazio).

**Traditional type of management**: in Italy more than two-thirds of chestnut forests (605,868 ha) are coppices or high forests attributed to the forest sub-category chestnut groves and only 19% are formations included in the sub-category chestnut and chestnut forest. 94% of the area is available for wood harvesting and in 81% of the cases there are no naturalistic constraints. Most Italian chestnut groves (91%) are concentrated in a few regions. Wood production is generally the predominant function, except in Campania where, on the contrary, 67% of the chestnut groves are used for fruit production.

**Forest habitat or forest type**: chestnut coppices

**Aims**: to define guidelines to promote the valorisation and also a new silviculture of chestnut coppices, through silvicultural approaches suitable for increasing and diversifying wood production, improving the stability and ecological functionality of the stands, reducing the environmental and social costs of wood imports, and promoting important carbon storage.

**Pressures/threats**: gradual and widespread abandonment of cultivation in chestnut groves, conversion to coppice of large areas and, in several cases, even the replacement of chestnut trees with exotic and fast-growing species. The high accumulation of biomass, and especially necromass, is a factor that contributes to an increased fuel load and thus susceptibility to fire. In fact, chestnut coppices are one of the forest formations affected by fires in no small way, accounting for about 10-20% of the fires that hit Italian forests from 2006 to 2011. The implementation of late thinnings or 'conversion to high forests' cuts do not induce appreciable improvements from a productive point of view. The main weak points for quality silviculture are linked to species characteristics such as susceptibility to pathogens, tendency to scab and sensitivity to climate change. Another limiting factor is the current structure of ownership (excessively fragmented and organised on small areas, characterised by uniformity of management) and of the supply chain (processing companies are mostly family-owned, with a low level of entrepreneurship and an inadequate degree of mechanisation).

**Case Study Description**:

Simple coppice treatment without release of standard trees valid for all coppice shifts.

- **Cutting mode:** create a rounded and domed shape of the stump to avoid water stagnation and encourage the emission of suckers in the lower part of the cut
- **Cutting time:** with regard to the cutting time, it has been demonstrated that, at least in southern regions, it is possible to coppice at any time of the year as this does not compromise the vitality and development of the stumps. Much attention must be paid, however, during the hauling phase which, in the case of coppicing during the vegetative period, must be timely so as not to damage the young shoots. Other interesting research has shown that there is an influence of the moon phase present at the time of felling on the properties of the wood; in particular in the waning moon phase the tendency to water loss and radial shrinkage is accentuated.
- **Cutting size -** reduce the size of the cut within 5 ha of contiguous area; in steeply sloping terrain erosion damage due to rainwater run-off is particularly harmful, especially in the first 2-3 years of the round, i.e. the time needed for the canopy to recover.
- **Tree specific diversity -** The choice of preserving valuable species other than chestnut should be made according to the silvicultural objective and the length of the rotation. If the silvicultural objective is quality wood production and the shift is longer than usual, it seems a good rule to release about 20 trees per hectare, preferably from seed, of good conformation, chosen from species with quality timber and able to withstand isolation. This rule is not in fact a substitute for matriculation as these are species with much slower growth rates than chestnut suckers.

If there is an obligation to issue standard trees, it would be absolutely necessary to define not only the minimum number, but also the maximum number. As a general rule, their number should be inversely proportional to the length of the shift and 50 units per hectare should not be exceeded. Standard trees should be chosen from among the other species that may be present or, in the case of pure coppices, follow the criterion of distribution in groups (5-6 groups per hectare made up of suckers of the same age as the coppice, in numbers proportional to the area occupied, which should not exceed 200 $m^2$).

- **Benefits**: the presence of standard trees, by limiting the space available to the stumps, affects the development and growth of young suckers and negatively affects the productivity of the coppice. The main positive effects, statistically significant, found in a simple coppice 10 years after coppicing are:
  - a lower mortality rate of suckers
  - greater diametrical growth;
  - a greater ground cover;
  - an increase in stump vigour.

These effects diminish with age although differences are still evident at 20 years. In the case of medium-long rotation the presence of standard trees, whose crowns can reach 60-70 $m^2$ in coppices of 50 years, is even more damaging as it negatively affects the vitality of the stumps with consequences for the next cycle due to the low number of residual stumps.

Management of medium and long rotation coppices

Shift lengthening accompanied by the application of appropriate silvicultural standards is the main practice to enhance the economic and environmental potential of the species, increase the quantity of products and improve the quality of the assortment.

a) **Stand silviculture**: it is applied when the silvicultural objective is the enhancement of the stand as a whole.
   - **Age of the first thinning**: 10 and 15 years depending on the length of the rotation, the fertility of the stand, the situation of the local wood market.
   - **Rotation lenght**: 30 and 50 years depending on the potential of the station, the incidence of tree diseases, the silvicultural objective and the quality of the products to be obtained at the end of the cultivation cycle.
   - **Thinning regimes** such as to maintain a balanced and functional dominant plane over time, with individuals with good morphological characteristics and regular and sustained growth. Regularity of growth is in fact one of the prerequisites for reducing the incidence of the onion defect in chestnut wood.
     - Thinning frequency: every 7 years, after verification of the dominant reference height values and recovery of the removed mass.
     - Intervention intensity 25 to 35% of the basal area.
     - Type of thinning from below or mixed.

Due to the high degree of cultivation required, the reference parameters for the practical application of these models must be:

- good and excellent stationary fertility, expressed by the dominant height values, which allows the productive capacity of the station to be exploited to the utmost, exploiting the high dynamism and strong reactivity of the species to silvicultural interventions;
- an adequate number of stumps. The low density of stumps (generally derived from the recent conversion to coppice of fruit chestnut groves) is indicative of a non-uniform spatial structure characterized by strong inter-individual competition for the high number of suckers on the stump. This can lead to morphological trunk defects, such as scabs and twisted trunks that contribute to lower timber value, and asymmetrical crowns, one of the causes of irregular radial growth. Ultimately, the low density of stumps limits any thinning intervention aimed at improving and increasing wood quality.
- Sufficient accessibility and viability to allow cutting, hauling and staking operations without damaging the released suckers.

**b) Tree-oriented silviculture**: the aim is to produce good and excellent quality timber with medium to long shifts and silvicultural methods that maximise yield in relation to investment.

When to use it in chestnut coppices:

- where there is no market for small-sized pole trees. In fact, the type of thinning envisaged makes it possible to obtain larger assortments already on the first intervention;
- when it is desired to obtain trunks of excellent shape and larger size in a shorter time than in stand silviculture;
- in the case of stands in which other valuable tree species are also present that require localised interventions to reduce competition from chestnut suckers.

Silvicultural criteria to be followed:

- Early selection, at about 10 years of age, of 80-100 target trees per hectare. The number of target trees to be released depends on the stationary characteristics, phytosanitary risks, the silvicultural objective of the property, and the length of the rotation. In the latter case, both the space requirements for free growth of the selected individuals and the damage from biotic and abiotic agents, which tend to be proportional to the length of the shift, that may affect the target trees, must be considered.
- Shift lengthening (30 to 50 years). The length of the shift also depends on the potential of the station, the incidence of plant diseases and the quality of the products to be obtained at the end of the crop cycle.
- Thinning regime characterised by the progressive isolation of the crowns through early, frequent, medium-intensity interventions from above.
  - The first thinning should be carried out at around 10 years of age, with dominant height values above 10 m, when the social difference of the individuals is already well evident.
  - The crown should always be left free to grow in a regular and symmetrical manner without undergoing competition processes. In general, interventions should be frequent in the juvenile phase and more spaced out with increasing age. In fact, a free space (dèturage) of about 2 m is necessary to allow the foliage to develop freely for a period of at least 3-5 years.
  - The intensity of intervention depends on the density of stumps and suckers close to the target trees; in general it is reduced with age and should not exceed 20-30% of the number of trees.
  - Thinning is from above; as a result, the assortments are on average larger than those obtainable with stand silviculture. This is particularly important when assessing the economic sustainability of the first thinnings.
- Pruning to be carried out, if necessary, the year after thinning in order to avoid drooping nodes in the final product. Generally, epicormic branches, if emitted, should disappear within 2-3 years as the size of the crowns ensures shading of the trunk but, if they persist, pruning should be carried out on the target trees

Necessity: applicable only in areas characterised by **good accessibility and stationary fertility**, but above all in the presence of **trained technical personnel** to avoid damage to the target trees during cutting and logging operations. **Crown growth must be monitored** to avoid competitive phenomena with neighbouring suckers. Lastly, it is appropriate to point out possible uncertainty factors concerning the presence of wildlife often attracted by isolated plants that they damage by rubbing or bark biting.

<u>From pure coppice to mixed forest</u>

Changing the form of treatment can be considered to recover unproductive, unstable systems of low environmental value located in ecologically marginal areas for the chestnut tree and to improve the use of resources in efficient systems where the dynamics of natural regeneration point to the possibility of management that is not limited to the enhancement of the chestnut tree alone. The aim is to increase mixing through the application of silvicultural interventions that facilitate the transition to a mixed forest. In the derived structures, the chestnut tree may play a more or less important role depending on the silvicultural objective and the silvicultural characteristics.

**In ecologically marginal areas for the chestnut** the introduction of other species or, if present, their enhancement, represents a suitable cultivation practice for the productive and environmental recovery of stands. Useful practices may be:

- the creation of gaps to encourage the spontaneous entry of other species in the event that there are woods with a different specific composition in the immediate vicinity, paying attention, however, to the presence of undesirable species, such as ailanthus (Ailanthus altissima) or robinia (Robinia pseudoacacia)
- the possible under-planting of valuable or shade-tolerant species (e.g. beech and silver fir at higher altitudes and typical oak species such as rosaceae, maple and ash at lower altitudes);
- the execution of diffuse thinnings in order to free the present regeneration or localised thinnings to favour the growth and fructification of single plants of high ecological or economic value;
- the coppicing of the stand.

**Under conditions of ecological suitability for chestnut** but where valuable tree species are present, the silvicultural methods described above can be used: stand silviculture and tree-oriented silviculture.

- The criteria of **tree-oriented silviculture** can be applied mainly when tree species other than the chestnut are present within the coppice with a discrete diametrical size and good conformation. The objective, especially in the case of valuable species, is twofold: i) to increase the diversity of the coppice; ii) to diversify and enhance the quality of wood products. The tool is the implementation of thinning operations that, by isolating the crowns, enhance diametric growth and favour seed production.
- The criteria of **stand silviculture** can instead be used in cases where the natural seed regeneration of species other than the chestnut is undergrown and still young. In the short and medium term the objective will be limited to ensuring balanced growth of the species to be favoured. Thinnings will be selective, at the expense of the upper storey of the stand and aimed at reducing density and cover.

**Reference document**: Manetti M. C., Becagli C., Carbone F., Corona P., Giannini T., Romano R., Pelleri F. 2017 - Linee guida per la selvicoltura dei cedui di castagno. CREA, Ed. Roma: 48 p. (Language: Italian)

### 1.3. Spain (Catalunia) - Adaptive and close-to-nature management in chestnut stands

**Project**: LIFE MIXFORCHANGE (LIFE15 CCA/ES/000060) - Innovative management strategies for adapting mixed sub-humid Mediterranean forests to climate change

**In brief**: The main objective of the project is to contribute to the adaptation and greater resilience of mixed sub-humid Mediterranean forests to climate change, favouring their conservation and the maintenance of their productive, environmental and social functions. Specifically, the project aims to: i) develop and implement innovative forest management techniques, which allow forests to adapt to climate change and improve ecological and economic value in the medium term; ii) develop new tools to integrate the adaptation of sub-humid Mediterranean forests to climate change into the policy and laws on forest management; iii) develop new tools to strengthen the economy linked to the products provided by these forests, preventing or reversing their abandonment; iv) transfer the tools and techniques developed and results obtained taking into account the main stakeholders (forest owners, technical staff and public administration) at a regional, national and European level, and raise social awareness on the challenge of adapting forests to climate change.

**Website**: www.mixforchange.eu

**Location:** Catalonia

**Territorial context**: the project activities have been implemented in 197 ha of mixed forest in the Catalan sub-humid Mediterranean, in four geographical areas in northeast Spain. The four areas where pilot demonstration stands were located are:

- Montnegre-Corredor: Littoral low mountain conditions (maximum altitude 760 m, distance to sea <10 km), warm temperatures and high precipitation (Foëhn), steep slopes, densely populated. Silica substrates.
- Montseny: Pre-littoral high mountain conditions (maximum altitude 1700 m, distance to sea 20-40 km), low winter temperatures and high precipitation (Foëhn), steep slopes. Silica substrates.
- Bellmunt-Collsacabra: Continental Mediterranean mountain conditions (maximum altitude 1300 m, distance to the sea> 50 km), low winter temperatures and medium precipitation, high slopes. Silica and calcareous substrates.
- Ripollès: Conditions of continental Mediterranean mountain, in transition to eurosiberian from Pyrenees (altitude maximum 1500 m, distance to the sea> 50 km), low temperatures in winter and average precipitation, high slopes. Silica and calcareous substrates.

**Traditional type of management**: conventional forest management or no silvicultural intervention in recent decades, after long periods of somewhat intense use

**Forest habitat or forest type**: 15 demonstrative chestnut stands have been intervened, some 46 ha in total.

**Aims**: the interventions' general aim is to promote the stands' resistance and resilience in the face of the main impacts of climate change, in a way which is compatible with economic and ecological sustainability in the medium and long term. In particular, the management of chestnut stands is focused on accompanying the change in dominance in favour of other broadleaf species already present (oak, holm oak, ash, cherry...) according to the micro-site, whether as individual trees or as regeneration patches.

**Pressures/threats**: sub-humid Mediterranean forests of great environmental, productive and social interest are subject to threats that jeopardize the provision of many of these ecosystem services. Although the stands are, in general, mixed and show a certain degree of stratification, the prevailing form of management has progressively led them to a certain point of structural and species simplification. The chestnut stands present an abundance of coppices which tend to present low vigour. The main threat posed by climate change in this context is the rise in the intensity of droughts and forest fires. Many of the species present (including ash, maple, chestnut and some oaks) are poorly adapted to these disturbances, making them especially vulnerable.

Most chestnut stands in Catalonia were planted in the first half of the 20th century to produce wood. Currently, many of these stands are abandoned and in a very poor state of health, generally due to the incidence of chestnut blight (*Cryphonectria parasitica*) and the failure to adapt to current site conditions

**Case Study Description**: this management approach makes chestnut stands advance toward a vertically and horizontally heterogeneous structure, with a trend toward regularization and capitalisation (where species change is in favour of oak) or toward irregularization (change in favour of holm oak). To the extent possible, broadleaf individuals and species with greater potential to produce valuable timber are encouraged, provided they show high vigour. As a result of the innovative silviculture, the stand takes shape as a mixed coppice-with-standards forest, with a regularized or irregularised structure depending on the dominant species in the medium term. The structure is primarily multi-layered: dominant chestnut trees if they are vital and trees of other already present species, intermediate stratum by patches, regeneration of accompanying broadleaves and chestnut sprouts. The interventions considered in the demonstrative chestnut stands include:

- **Selective thinning:** the first step is to perform a selection of future crop trees (some 100 to 200 trees/ha, maximum 1/4 of the total density), primarily including vital and well-shaped valuable broadleaved trees (including chestnut, if viable) preferably from diametric class 15 and up but with time to grow, and also individuals with interest for biodiversity conservation (underrepresented species, trees with microhabitats of interest, seed trees and fruit producers). In addition, occasional release and pruning may be considered for valuable broadleaved trees which fail to reach the aforementioned diameter if they show good vigour and robust, well-shaped trunks. Selective thinning consists in regulating the competition to which future crop trees are subject, eliminating their main competitors on the canopy level. The number of individuals to eliminate per future crop tree determines the thinning intensity: as a reference point, between 1 and 2 competitors are felled, with a lower value the more future crop trees selected and the more compressed their crown. As a general rule, the extracted basal area does not exceed 25-30%. The felled trees can either be extracted or kept in the soil, depending on their value. Another possibility is to girdle competitor trees instead of felling them to make the future crop tree's initiation of light exposure more gradual. The individuals close to the future crop tree not identified as competitors on the canopy level are maintained, thereby creating a service layer which supports the proper configuration of the selected tree and prevents the emergence of epicormic shoots. In the stands or parts of the stand which diverge from the optimal characteristics for applying MixForChange silviculture (simplified structure, very high density and/or scarce or null stratification, abundant coetaneous regeneration), may systematic thinning be considered, without taking individual characteristics into account.
- **Shoot selection (sucker cutback)**: intervention used to regulate competition on the tree level, applied on stumps with many shoots to concentrate growth in the best developed and positioned ones. One or two shoots are typically left per stump, although in chestnut trees, from one to four may be left regardless of the density (fewer shoots the larger their size). On

these chestnut stumps, usually only the adult (dbh > 7.5 cm) living shoots are considered, leaving the dead and small-sized living shoots without cutting. On the stand level, shoot selection also reduces competition and improves vitality.

- **Selective clearing**: partial elimination of the vegetation of the understory layer, based on a prioritization by height, species or vitality. Optionally, a total target coverage range may be established to reduce overall vulnerability to forest fires. In chestnut stands with full coverage the understory tends to be scarce, which is why clearing operations are limited to facilitating access and promoting the desired tree or shrub species, for their economic or ecological interest.
- **Rejuvenation**: cutting misshapen individuals from target broadleaf species down to the ground in order to stimulate a new shoot which may be better shaped. The individual to be rejuvenated is typically young and must show sprout capacity and favorable micro-site conditions. The individuals cut during rejuvenation may be extracted or left in the soil, depending on their commercial value.
- **Planting**: artificial regeneration of areas of low tree cover showing null or insufficient regeneration. A great diversity of species are planted, with densities between 10 and 250 trees/ha, taking advantage of the most favorable micro-sites and applying complementary planting techniques to augment success, such as individual shelters or soil conditioners.
- **Marking:** the marking is performed in a part of the stand in a demonstrative way (training area), where the field crews who execute the interventions are accompanied and capacitated.

The total costs fall between 1,850 and 4,200 €/ha

**Reference document**: Coello J, Piqué M, Beltrán M, Coll L, Palero N, Guitart L. 2022. Adaptive and close-to-nature management in mixed sub-humid Mediterranean forests: holm oak, chestnut, common oak and pine woods. Forest Science and Technology Centre of Catalonia, Solsona (Lleida, Spain); Forest Ownership Centre, Santa Perpètua de Mogoda (Barcelona, Spain). 104 p. (Language: English)

# 2. CORK OAK FORESTS - Habitat 9330 *Quercus suber* forests

## 2.1. Spain (Catalonia) - Innovative management measures to increase the resilience of cork oaks to forest fires

**Project**: LIFE+ SUBER (LIFE13 ENV/ES/000255) - Integrated management for an improved adaptation of cork oaks forests to climate change

**In brief**: Cork oaks forests are a typical element of the Mediterranean landscape and their productive, environmental and socio-cultural functions are of great interest. This system is currently in a highly vulnerable condition. In fact, the Mediterranean is one of the most critical area from climate change point of view. The main purpose of the project is to improve the adaptation capacity of the cork oak trees to climate change, promoting their conservation and the maintenance of the value chain linked to the production of cork, through the following points:

- improving the vitality of the cork oak forests and their resistance to drought while increasing the production of cork;
- improving the resilience to climate change of degraded cork oaks;
- improving the structure of cork oak trees to increase their resistance / resilience to forest fires;
- reducing the damage caused by Coraebus undatus through biorational methods;
- developing management tools and supporting the adaptation to climate change into management policies.

**Website**: www.lifesuber.eu

**Location:** Catalonia

**Territorial context**: in Catalonia, cork oak forests occupy an area of about 69,000 hectares. Within this area, the LIFE + Suber project has concerned 4 different areas for their ecological characteristics that represent the diversity of the environmental conditions of the Catalan cork oaks:

- Alt Empordà: is a Comarca of Catalonia, located in the province of Girona, in the north-eastern part of the Catalan region with a cool and moderately rainy climate. The area is battered by high winds and frequent intense forest fires.
- Gavarres: represents the northernmost area of the Catalan coastal cordillera. The climate is generally mild with dry summers, in the coastal strip it is strongly influenced by the sea.
- Montseny-Guilleries: part of the Catalan pre-coastal cordillera, the highest point of which is the Montseny massif (1707 m a.s.l.). The climate is relatively colder and rainy than the other areas of intervention.
- Montnegre-Corredor: the Montnegre and Corredor massifs are two well-defined mountainous units that form part of the Catalan coastline cordillera. The climate is temperate, warm and rainy, characterized by high humidity and strong influence of the sea.

**Traditional type of management**: previous management of project sites:

Alt Empordà/ Mas Genís: this forest is made up of cork oak forests characterized by large crowns and with signs of pruning carried out in the past. It is probably an ancient dense dehesa (cork oak forest with a lower layer of pastures and strong human influence);

Alt Empordà/Mas Descalç: forest adjacent to that of Mas Genís. It is a forest stand very similar to that described above, but located in an area characterized by less good stationary conditions;

Gavarres/Mas Fonollet: forest adjacent to an already existing protection strip, realized next to the main track. Quercus plants are associated with (high suber *Arbutus unedo* density) and *Quercus ilex*;

Gavarres/Can Noguera: forest located next to a road around which, in some traits, it has begun to create a protection zone for fire prevention. It is a forest abandoned for many years, with a very dense and high undergrowth (height similar to that of cork oaks). Many trees present the attacks of *Diplodia mutila*;

Montseny-Guilleries/Can Joandó: this forest was affected by the fire of Sant Feliu de Buixalleu in 1994. The intensity of the fire was medium-low and the trees resulted in little damaged. It is a young cork oak forest and almost all individuals are characterized by male cork;

Montseny-Guilleries/Can Iglesias: also this forest was affected by the fire of Sant Feliu de Buixalleu in 1994. But in this case the trees were very damaged, given the construction of the cork collection a few years before the fire. Since the year of the fire, the collection of cork has not taken place;

Montnegre-Corredor/Can Preses: this forest is characterized by areas with a high concentration of *Arbutus unedo* and *Erica arborea* which prevent sunlight into the forest crowns;

Montnegre-Corredor/El Truy: in this forest forestry treatments have been carried out for a few years, to eradicate mainly pine trees. At the time of the intervention there were still waste materials and some cork dead on the ground.

**Forest habitat or forest type**: cork oak forests, habitat 9330.

**Aims**: improve the structure of the cork oak forests to enhance their resistance and resilience to forest fires and at the same time, favor the production of cork. The interventions aim to create an open structure in order to give discontinuity of forest fuel. In this regard, the undergrowth cleaning and occasional cuts are carried out, with the release of the best trees for the production of cork.

**Pressures/threats**: climate change, the increase in forest density and the increase of forest area, are the main factors that contribute to increase the extent and the intensity of forest fires in the Mediterranean areas. Although the cork oak forest is a system relatively adapted to the fire, because of the production of cork that protects trees, high intensity fires can cause serious damages, especially if they occur in the years following the collection of cork when the plants no longer have the protection layer.

**Case Study Description**: The techniques used at the time of the project are innovative and economically sustainable, compared to traditional forest management techniques for fire prevention. Furthermore, with this type of management it is expected a greater production of cork up to 4,000-5,000 kg / ha in 14 years on sites characterized by good stationary conditions.

The innovative forest management techniques used in this project, are based on the specific cork oak forests Guidelines for Sustainable Forest Management in Catalonia (ORGEST). The intervention sites must be identified in Strategic Management Points, i.e. in areas where operations for control and slowing down of the propagation and fire extinction, can be easily carried out.In each intervention site, a permanent intervention area and a plot adjacent to the first with similar conditions are created.

The silvicultural interventions specifically used in this practice consist of a combination of the following operations:

- selective cleaning of the undergrowth, with release of species such as Arbutus unedo and eradication of more flammable ones. The cleaning intensity can vary from 90-100% to 40-60% of the shrub cover;
- high intensity chosen cutting (> 40% of the initial basimetric area);
- treatment of waste material to avoid the risk of fire (generally by cutting it in situ to obtain small material, facilitating the decomposition) and mechanical extraction or shredding in areas adjacent to forest tracks.

After carrying out the silvicultural operations described above, it is recommended the use of the treated areas for grazing to ensure the maintenance of the open structure. To assess the effect of the practice, dendrometric measurements are carried out before the intervention, immediately after, and after two vegetative periods after the intervention.

Specifically, dendrometric measurements include:

- inventory of the undergrowth before its cleaning in the areas of intervention, and inventory of the undergrowth and tree layer in the witness plots;
- inventory of the undergrowth after cleaning it, and inventory of the arboreal layer before chosen cutting in the intervention areas;inventory of the tree layer immediately after the realization of the chosen cut;
- inventory of the undergrowth and the arboreal layer two vegetative periods after treatment in the intervention areas and in the witness plots;
- monitoring of plant viability (NDVI).

In order to assess the medium-term impact of the interventions, monitoring activities must be repeated over time.

In sites characterized by good stationary conditions, the operations cost to carry out the practice was on average of 1.000 €/ha for the cleaning of the undergrowth; 660 €/ha for the chosen cutting and management of the waste material; total cost 1.505 €/ha.

In sites characterized by less good stationary conditions, the operations cost to carry out the practice was on average of 800 €/ha for cleaning the undergrowth; 653 €/ha for the chosen cutting and management of the waste material; total cost 1.365 €/ha.

**Reference document**: Beltrán, M.; Coello, J.; Mundet, R. 2017. Descripción técnica de los modelos innovadores de gestión para mejorar la resiliencia de los alcornocales frente a grandes incendios forestales. Proyecto Life+SUBER (LIFE13 ENV/ES/000255)

## 2.2. Portugal - towards a sustainable forest management of cork oak forests

**Project**: Companhia das Lezírias, S.A.

**In brief**: The Companhia das Lezírias, S.A. (CL), founded in 1836 by private shareholders, became public in 1975. It is one of the country's largest agroforestry companies responsible for managing approximately 19 500 ha with a large diversity of economic activities: production of rice, maize, wine and olive oil; cattle and horse breeding; forestry; and tourism. Because of its proximity to Lisbon, and conditions stemming from its inclusion in the Natura 2000 Network, as well as the fact that it sits on Portugal's largest aquifer, CL's business model aims to maximize the forest's contribution towards human well-being, especially where ecosystem services are concerned.

**Website**: https://www.cl.pt/

**Location:** area of Tagus estuary (Lisbon)

**Territorial context**: the largest property, 'Charneca do Infantado,' is made up of 11 000 ha and located 30 minutes northeast of Lisbon. The forest occupies 8840 ha, of which 6600 ha are cork oaks (*Quercus suber*), with variable tree density (average of 80 trees/ha) where most of the forest area is used for cattle grazing, making up the agroforestry system typical of southern Portugal (montado – 22 % of the Portuguese forest – 720 000 ha). The umbrella pine (*Pinus pinea*) appears in pure stands and mixed with cork oaks (680 ha). Because of the proximity to the Tagus estuary and the Atlantic, the forest also features 1000 ha of maritime pine (*Pinus pinaste*r) (fig. C 14.4) and 560 ha of eucalypt *(Eucalyptus globulus*); thus, the country's four most important forest species in regard to area and economy are present.

**Traditional type of management**: agroforestry system. The management system is extensive (rather than intensive), and concentrates mainly on production of non-wood products such as cork, pasture, and pine nuts.

**Forest habitat or forest type**: cork oak forests

**Aims**: CL's business model aims to maximise the forest's contribution towards human well-being, especially where ecosystem services are concerned

**Pressures/threats**: In areas with cork oak the goods and services they produce in addition to cork, limit the way the area is managed. The need to maximise the production of cattle forage leads to a simplified vegetation structure resulting in a low diversity of habitats and species. The physical presence and concentration of cattle has a negative impact on the regeneration of cork oaks and results in compression of soils. With the apparent decrease in rainfall, and an increase in the number of heat waves, the changeover to species such as the maritime ine and cork oaks have made the signs of cork oak and maritime pine increasing inadaptation, both in regard to the growing decline and mortality of trees, as well as their less vigorous natural regeneration

**Case Study Description**: The agroforestry system in place exists in areas of poor soil and water limitations during the summer season, which limit the system's primary productivity.

The management system is extensive (rather than intensive) and concentrates mainly on production of non-wood products such as cork, pasture, and pine nuts. The harnessing of the pasture is done by allocating, on average, one cow per two hectares of land during six months, which enables the entire pasture to go into organic production mode. Pastures are the result of natural vegetation or are improved seedling of other herbaceous species for periods of 10 years. Every year cork is extracted from a determined area since it normally takes nine years to grow. Once the trees have died, they are used for firewood. The main management activities revolve around the regeneration of the cork oak, using natural or artificial protection, but they also include pruning young trees, and controlling invasive pines and shrubs. In part of the area (36%), pasturing does not take place; instead, there is an area composed of cork oaks, and cork oaks with maritime and/or umbrella pines, with a tendency for an increase in tree coverage. Furthermore, Iberian pigs graze in the montado between November and February. The maritime pine is thinned every ten years, in 40-to-50-year cycles. Umbrella pines produce a highly valuable edible seed (pine nut); the pinecones are harvested by the buyer, who then extracts the pine nuts. For all three species, the management systems are highly dependent on natural regeneration to guarantee new plants are well adapted. Compatibility with grazing implies the protection of individual plants, particularly of cork oaks under 15 years, which are protected with wire tree guards. Close to 29 600 guards have been installed. The forest receives 6500 visitors annually: 76 % are visitors taking part in paid activities, and the remainder take part in community activities. The entire area's forest management is sustainably certified.

The challenge over the last two decades has been to mitigate the effect of landscape homogenisation and degradation of water courses, while simultaneously promoting wild species occupancy and population connectivity to ensure gene flow.

Examples of measures to achieve such goals are:

- establishing grazing-exclusion plots to promote cork oak natural regeneration and conservation purposes;
- designation of the cork oak stands as a model forest with international certification, improving the general condition of the stands by preserving the soil, protecting natural regeneration and controlling tree health; and
- since 2005, using natural pastures, direct sowing or the establishment of permanent legume-rich biodiverse pastures (currently >3000 ha), as a way to enrich the soil, fix organic matter and remove carbon from the atmosphere, a service remunerated by external entities.

One successful example of these actions was the implementation of a green corridor as a management tool to improve connectivity for birds and mammal communities that involved the restoration of degraded watercourses and the planting of strips of native species to act as linkage elements.

Another line of action CL is investing in is the recovery of the wild rabbit (*Oryctolagus cuniculus*), a potential provisioning service as a game species, but also a valuable food resource as prey for carnivores and raptors, and whose local monitoring activities have demonstrated a continuous declining trend. To counteract this trend, translocation of individuals from places of high abundance to places of low abundance, without resorting to outside genetic material was tried. In addition, the captive breeding from a stock of individuals resistant to the epizootics, which are the main cause of death of the species, with the offspring to be released in the wild, will soon follow.

This measure also further supports the two pairs of threatened Bonelli's eagles that were found (2008 and 2016) nesting in two mature maritime pine stands. Planned clear-cutting and other operations were cancelled when the eagles were found.

While management practices are adjusted for protection of endangered bird species, common birds can be allies of sustainable forest management providing balance to the ecosystem functioning. Insectivorous birds play an essential role as regulators of their prey populations and have the potential to combat forest pests without prejudicing the ecosystem.

CL forest productivity has been affected by defoliator insects, especially the pine processionary moth (*Thaumetopoea pityocampa*) in pine stands, and the European oak leafroller (*Tortrix viridana*) and the sawfly (*Periclista andrei*) in cork oak stands. Because many insectivorous birds in pine and cork oak stands are cavity-nesters, a nest box installation programme directed at these species was implemented, aimed at increasing their populations.

The project also includes a **strong social component** on three fronts:

1. Taking on social responsibility through direct and indirect job creation;
2. Developing a variety of tourist products and services and structuring a business that will serve as an example for other agents in the sector;
3. Increasing knowledge about forest systems and natural heritage through research opportunities and creation of educational initiatives.

CL is an ideal case for studying stakeholders' involvement in defining problems and solutions, and social learning.
**Resilience:** besides establishing permanent biodiverse pastures as a carbon sink, reducing the grazing pressure on the system is also a target in the near future. Establishing grazing-exclusion and conservation plots were essential measures to restore a degraded forest because of the legacy of resource overexploitation. Although positively affecting carbon sequestration, soil fertility, and biodiversity, shrub development may have unintended effects in a scenario where water is a limited resource for the functioning of the forest ecosystem.

Economic results: 1) Annual average forest results 1.04 x 106 €; 2) Annual average cork oak results 0.805 x 106 €; 3) Annual average cork sales 0.916 x 106 €; 4) Average sales of wood 0.177 x 106 €; 5) Average sales of pinecones 0.137 x 106 €

**Reference document**: Krumm, F.; Schuck, A.; Rigling, A. (eds), 2020: How to balance forestry and biodiversity conservation – A view across Europe. European Forest Institute (EFI); Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Birmensdorf. 640 p

# 3. HOLM OAK FORESTS /OAK FORESTS - Habitat 9340 *Quercus ilex* and *Quercus rotundifolia* forests

## 3.1. Italy - Demonstrative Forest Pro Silva: Podere Seradino

**Project**: Demonstative Forests of Pro Silva Italia

**In brief**: the project consists of a selection of Italian forests considered to be particularly significant for expressing the management approach proposed by PRO SILVA, in situations that are also very different in terms of status, climate and social economy. The demonstration forests identified so far by Pro Silva Italia are located at Col de Joux (Val d'Aosta); Podere Seradino (Umbria); Bosco delle Sorti della Partecipanza (Piedmont); Forests managed by the Consorzio Forestale Alta Valle Susa (Piedmont); Chestnut groves of Monte Amiata (Tuscany); Beech forests of Monte Amiata (Tuscany).

**Website**: https://www.prosilva.it/foreste-dimostrative

**Location:** Monte Malbe mountain complex (Umbria Region)

**Territorial context**: The Monte Malbe area has special characteristics that are the expression of different bioclimatic influences. The Mediterranean vegetation of evergreen and deciduous sclerophyllous trees is represented on the southern slopes by extensive holm oak forests, with a more inland association of thermophilic turkey oak. On the northern slopes there are coppice woods of black hornbeam, and juniper and broom shrubs are widespread in the clearings.

**Traditional type of management**: the current property is owned by the Rossi family, who purchased the forest in 1974 from the Conti Salvatori, who carried out coppicing on all 100 hectares, saving only a few hectares because they were used as hunting grounds for wood pigeon. In the 1990s, the first silvicultural interventions were carried out, converting 10 hectares of coppice into high forest. From 2008 to 2011, the property adopted an innovative forest management plan, with interventions on small coppicing areas (less than 5 hectares/year) with the release of elite trees of valuable wood species, combined with start-up interventions in the impluvial areas in order to articulate different forms of forest governance on the hillside. Silvicultural activities have been discontinued since 2011, with the establishment of a farm that will manage according to the criteria of sustainable forest management and good silvicultural practices.

**Forest habitat or forest type**: holm oak forests, habitat 9340

**Aims**: silvicultural management that takes into account the environmental and structural characteristics of the forest and seeks to combine naturalistic-ecosystemic aspects with economic aspects in a manner that is innovative for central Italy.

**Pressures/threats**: coppice management prevails in central southern Italy and there is little valorisation of wood products that may have a productive destination other than firewood.

**Case Study Description**: the forest represents a particularly interesting example of silvicultural management that takes into account the environmental and structural characteristics of the forest and seeks to combine naturalistic-ecosystemic aspects with economic aspects. The management methods applied are innovative for central-southern Italy, where coppice management prevails and there is little valorisation of wood products that can have a productive destination other than firewood. In particular, the indications of the Forest Management Plan envisage a mosaic of interventions with areas of natural evolution, even-aged high forests, irregular high forests, coppices with group standards, coppices with uniform standards. The management practised from 2008 to 2011 is that of interventions on small coppicing areas (less than 5 hectares/year) with the release of elite trees of valuable wood species, combined with start-up interventions in the impluvial areas in order to articulate on the hillside different forms of forest management.

**Holm oak forest with other deciduous broadleaf trees.** The stands are to be considered as coetaniform. Depending on the evolutionary stage of the forest, the density of the trees per hectare must be regulated by appropriate intercropping that will gradually lead the stand to the higher evolutionary stage. In order that the intercutting does not have an excessive intensity (considered inappropriate for the forest type), intervention parameters are prescribed as indicated in the table below.

| PRESCRIZIONI PER I TAGLI INTERCALARI PER LA FUSTAIA DI LECCIO CON ALTRE LATIFOGLIE DECIDUE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Stadio evolutivo | N/ha<br>n. | G/ha<br>mq | V/ha<br>mc | H<br>m | età indicativa<br>anni | PRELIEVO<br>% - G/ha | APERTURE AMMESSE<br>N /ha | SUPERFICIE APERTURE<br>m² | DISTANZA TRA CHIOME<br>m |
| novelleto | > 5.000 | <1 | - | < 2 | 0 - 14 | - | - | | |
| spessina | < 5.000 | > 1 e < 5 | > 1 e < 20 | > 2 e < 5 | 10 - 25 | MAX 25% | MAX 5 | 50 | < 2 |
| perticaia | < 3.000 | > 5 e < 15 | > 20 e < 100 | > 5 e < 8 | '20 - 40 | MAX 25% | MAX 3 | 150 | < 3 |
| fustaia giovane | < 1.000 | > 15 e < 25 | > 100 e < 150 | > 8 e < 14 | 35 - 65 | MAX 25% | MAX 3 | 200 | < 4 |
| fustaia adulta | < 500 | > 25 | > 120 e < 200 | > 9 | 65 - 100 | MAX 20% | MAX 3 | 400 | < 5 |
| fustaia matura | < 300 | > 25 | > 200 | > 9 | 100 - 140 | MAX 15% | MAX 5 | 500 | < 5 |
| fustaia in rinnovazione | < 100 | > 5 e < 25 | < 150 | > 9 | >120 | TAGLI DI RINNOVAZIONE | | | |

For regeneration cuts, even if not foreseen in the operational part of the above plan, hole cutting with natural regeneration is foreseen. The location of the gaps where hole cutting, i.e. the cutting of all trees, is to be carried out are areas with established natural regeneration and depressions or plateaus where the seed can stop. Hole cutting will affect cutting areas of no more than 2,000 $m^2$ and a maximum of 25% of the total productive area of the UC. The portions of the forest between the holes may be affected by thinning interventions with an intensity equal to the interventions envisaged for the mature forest and described in the table above. After the natural regeneration reaches a height of more than 50 cm, as long as it is free of herbaceous and shrub competition, and with a horizontal distribution on the ground that covers more than 66% of the gap surface area (definition of *novelleto*), a new cycle of hole cutting may be carried out, envisaging the enlargement of the hole or the creation of new ones. The enlargement of the gaps must respect the surface area limits defined above, i.e. holes not exceeding a total of 4000 $m^2$ for the second renewal cycle and 6000 $m^2$ for the third renewal cycle. In the event that the regeneration has not established itself within 10 years of the intervention, underplanting or planting with holm oak, manna ash, mountain ash, maidenhair, oak.

**Élite high forest -** This type of sporadic species high forest has the following elite species: the rowan, the jackdaw, the sycamore, the sycamore maple, the cherry, the oak, the turkey oak and particular trees of other species with uncommon stature. The silvicultural guidelines are closely linked to the concepts defined in tree-oriented silviculture, as conceived and described by various authors, distinguishing four stages: 1) establishment (or affirmation of regeneration); 2) qualification; 3) sizing; 4) maturity. The four phases of tree development are briefly described below, and the cultivation guidelines envisaged for the management of the species concerned (rowan, jackdaw, maple minor, cherry and oak) are hereafter referred to generically as Élite. They are distinguished into single and grouped elite trees, where the latter are considered to be such when the distance between them does not exceed 12 m.

The **establishment stage** is the phase in which the elite tree starts from the seedling stage until it overcomes competition from low shrubs and grasses or adjacent trees (social class: dominated). At this stage, only silvicultural measures are envisaged to reduce competition from low shrubs and grasses by cutting down to a maximum of 1 metre measured from the base of the tree. The cut material must be shredded and piled around the foot of the selected trees, taking care not to cause damage to the foot of the young trunks. Pruning of branches is envisaged in the event that neighbouring trees or tall shrubs may adversely affect or damage the growth of the Élite tree, and the installation of a guardian pole. In the event that the tree presents a severe trunk conformation, coppicing can be envisaged as an intervention.

The **qualification stage** is identified with the co-dominant social class in which minimum productive aims have been reached (2.5 m of trunk) but longitudinal development is still preponderant with respect to the structuring of the canopy architecture. In this phase all the trees that are 5 m from the base of the Élite species are subject to the following silvicultural guidelines and therefore excluded from those envisaged for the management of the coppice and holm oak forest with other deciduous broadleaf trees. At this stage, direct silvicultural guidelines are envisaged for elite trees and indirect guidelines for competing trees. Branch pruning along the trunk and cutting of suckers at the base of the trunk are foreseen in order to reach the potential trunk length. The cuts will have to be flush with the main trunk, taking care not to damage the lower rim of the branch and will involve branches with diameters of less than 5 cm, up to a height of 10 m from the ground. Green pruning must be carried out gradually and may not eliminate more than ¼ of the foliage, with a frequency of intervention not exceeding one every 5 years. The following cultivation operations are foreseen: cercination and cassage of trees adjacent to elite trees that compete directly for air space. Cassage is performed on competing trees by means of a cutting tool that scratches the endodermis down to the living part of the cambium, in practice the tree should not die off immediately but gradually over several years, gradually losing vigour and dominance. Cassage, a French term meaning breaking, involves bending until the branches or tops of competing trees break off. Bending must be carried out above 1.7 m from the ground, with a frequency of intervention of no more than one intervention every 5 years. In the event that the tree presents a severe trunk conformation, coppicing may be envisaged as an intervention.

The **sizing stage** is identified when the elite tree has reached the social class of dominance and the development of canopy architecture preponderates over longitudinal growth. In this stage, elite trees must progressively increase the size of the canopy in order to provide more photosynthetic capacity for good and constant diametrical growth of the main trunk. In this phase all the trees that are 10 m from the base of the Élite species are subject to the following silvicultural guidelines and therefore excluded from those envisaged for the management of the coppice and holm oak forest with other deciduous broadleaf trees. In this phase, direct silvicultural guidelines are envisaged for elite trees and indirect guidelines for competing trees. Direct interventions are those of pruning epicormic branches developed along the trunk to be obtained and all root suckers, as long as they are more than 5 cm in diameter. Indirect interventions on species other than Élite are the thinning and pruning of branches that occupy the aerial space necessary for the development of the foliage of Élite trees, in an area no more than 10 m from the stem of the Élite species. Thinning must in any case avoid abrupt interventions to open up the state of the crowns, which can create a strong emission of epicormic branches along the trunk. The intervention frequency must not exceed one intervention every five years.

The **maturity stage** is identified by the moment when the trees have reached the minimum diametrical size for production of the first trunk and the crown has reached 70% of the predetermined diametrical development. In this phase, elite trees maintain a certain rate of diametrical growth that can allow them to reach diameters that are more in demand in the veneer and veneer market (40 - 50 cm) in a not too long time (10 - 20 years longer than estimated), thus considerably increasing profitability. At this stage, cultivation guidelines are exclusively directed towards elite trees, and generally of modest size, i.e. pruning any epicormic branches in the first and second trunk and cutting any suckers. The intervention frequency must not exceed one intervention every five years. The decision to continue the growth of some Élite trees depends on the tree's ability to maintain the diametrical growth rate and the presence of excellent characteristics of the main trunk.

**Newly-formed forests -** the cultivation guidelines envisaged in this Forest Management Plan are those aimed at enrichment and undergrowth in areas of low density. Prevalence is given to the tree planting of the species of rowan, jackdaw and cherry, while holm oak and flowering as accessory species are envisaged. The planting of elite and accessory species is to be carried out in areas where there is a low density of trees and strong invasion by shrubs and grasses. Cultivation guidelines foresee the cutting of shrubs and grasses with the opening of holes measuring 40x40x40 cm by hand or with mechanical means dug at the points where the soil is deepest and grouped in 3 or 5 gaps at a distance of no less than one metre between them.

**Coppices -** The generic prescriptions for the management of coppice-governed forests with a prevalence of the Holm oak species with a standard tree between 100 and 180 trees per hectare are the release of the standards evenly distributed between 120 and 180 trees per hectare with a distribution that in the case of stands older than 45 years, 50% from trees coming from the previous rounds and 50% from suckers, while those younger than 45 years the release of standard trees will be 2/3 trees coming from the coppice and 1/3 from the previous rounds. The optimal shift for cutting is between 26 and 45 years. The shift limit for holm oak management is considered to be 60 years, after which the stand management will be converted to high forest. In the case of coppice-governed forests with less than 100 and more than 180 standard trees per hectare the release of the standard will be mixed with the prevalence of groups and the distribution of groups will follow the release scheme below.

TABELLA INDICATIVA PER LA MATRICINATURA A GRUPPI

| Altezza media matricine | diametro gruppo m | | superficie gruppo m² | | distanza tra gruppi m² | | numero gruppi N/ha | | |
|---|---|---|---|---|---|---|---|---|---|
| m | min | max | min | max | min | max | max | min | medio |
| 4 | - | 4 | - | 13 | - | 6 | | 69 | |
| 5 | - | 5 | - | 20 | - | 7,5 | | 47 | |
| 6 | - | 6 | - | 28 | - | 9 | | 34 | |
| 7 | 4 | 7 | 13 | 38 | 7 | 10,5 | 59 | 26 | 43 |
| 8 | 6 | 8 | 28 | 50 | 8 | 12 | 39 | 20 | 30 |
| 9 | 6 | 9 | 28 | 64 | 9 | 13,5 | 34 | 16 | 25 |
| 10 | 6 | 10 | 28 | 79 | 10 | 15 | 30 | 13 | 22 |
| 11 | 6 | 10 | 28 | 79 | 11 | 16,5 | 27 | 12 | 20 |
| 12 | 6 | 12 | 28 | 113 | 12 | 18 | 25 | 9 | 17 |
| 13 | 7 | 12 | 38 | 113 | 13 | 19,5 | 20 | 8 | 14 |
| 14 | 7 | 13 | 38 | 133 | 14 | 21 | 18 | 7 | 13 |
| 15 | 8 | 13 | 50 | 133 | 15 | 22,5 | 16 | 7 | 12 |
| 16 | 8 | 12 | 50 | 113 | 16 | 24 | 14 | 6 | 10 |

La matricinatura per gruppi interesserà tutta la superficie dell'u.d.c., anche se suddivisa in due o più interventi selvicolturali. La distanza tra il margine del gruppo e il piede d'albero sarà compresa tra i 10 e 8 metri.

The choice of the trees that will make up the group is based on the principles of biomechanical stability and is generally identified in at least 3 or 4 trees with a good conformation of the crown and trunk that function as the group's supporting columns. The species that will predominantly make up the groups will be the species with the highest density but all different species will be included as long as they have good bearing and a well-structured crown. The standard for groups will cover as far as possible the entire area of the unit; in the event that it is not possible to recruit a valid group of trees according to the above definition of a group, it is possible to release at a distance of 10 and 8 metres measured from the foot of the last tree belonging to a group to the foot of the tree to be released. Excluded from coppicing are all elite trees (rowan, jackdaw, sycamore, sycamore, cherry and oak). In addition, all trees other than elite trees that are 5 m from the foot of the elite species if they have reached the qualifying stage and 10 m if they have reached the sizing stage or later are excluded from coppicing.

**Reference document**:"Le foreste dimostrative di PRO SILVA ITALIA. Scheda 02 - PODERE SERADINO".

## 3.2. Spain (Catalunia) - Adaptive and close-to-nature management in holm oak stands

**Project**: LIFE MIXFORCHANGE (LIFE15 CCA/ES/000060) - Innovative management strategies for adapting mixed sub-humid Mediterranean forests to climate change

**In brief**: The main objective of the project is to contribute to the adaptation and greater resilience of mixed sub-humid Mediterranean forests to climate change, favouring their conservation and the maintenance of their productive, environmental and social functions. Specifically, the project aims to: i) develop and implement innovative forest management techniques, which allow forests to adapt to climate change and improve ecological and economic value in the medium term; ii) develop new tools to integrate the adaptation of sub-humid Mediterranean forests to climate change into the policy and laws on forest management; iii) develop new tools to strengthen the economy linked to the products provided by these forests, preventing or reversing their abandonment; iv) transfer the tools and techniques developed and results obtained taking into account the main stakeholders (forest owners, technical staff and public administration) at a regional, national and European level, and raise social awareness on the challenge of adapting forests to climate change.

**Website**: www.mixforchange.eu

**Location:** Catalonia

**Territorial context**: the project activities have been implemented in 197 ha of mixed forest in the Catalan sub-humid Mediterranean, in four geographical areas in northeast Spain. The four areas where pilot demonstration stands were located are:

- Montnegre-Corredor: Littoral low mountain conditions (maximum altitude 760 m, distance to sea <10 km), warm temperatures and high precipitation (Foëhn), steep slopes, densely populated. Silica substrates.
- Montseny: Pre-littoral high mountain conditions (maximum altitude 1700 m, distance to sea 20-40 km), low winter temperatures and high precipitation (Foëhn), steep slopes. Silica substrates.
- Bellmunt-Collsacabra: Continental Mediterranean mountain conditions (maximum altitude 1300 m, distance to the sea> 50 km), low winter temperatures and medium precipitation, high slopes. Silica and calcareous substrates.
- Ripollès: Conditions of continental Mediterranean mountain, in transition to eurosiberian from Pyrenees (altitude maximum 1500 m, distance to the sea> 50 km), low temperatures in winter and average precipitation, high slopes. Silica and calcareous substrates.

**Traditional type of management**: conventional forest management or no silvicultural intervention in recent decades, after long periods of somewhat intense use.

**Forest habitat or forest type**: holm oak forests, habitat 9340

**Aims**: The interventions' general aim is to promote the stands' resistance and resilience in the face of the main impacts of climate change, in a way which is compatible with economic and ecological sustainability in the medium and long term. In particular, the management of holm oak woods is centred on increasing the system's complexity, generating and maintaining irregular multi-layered structures, with a trend toward capitalisation, and supporting the development of different broadleaf species in conjunction with the holm oak layer.

**Pressures/threats**: sub-humid Mediterranean forests of great environmental, productive and social interest are subject to threats that jeopardize the provision of many of these ecosystem services. Although the stands are, in general, mixed and show a certain degree of stratification, the prevailing form of management has progressively led them to a certain point of structural and species simplification. The holm oak and chestnut stands present an abundance of coppices which, in the case of chestnut, tend to present low vigour. The pine stands often show an advanced senescence process. The main threat posed by climate change in this context is the rise in the intensity of droughts and forest fires. Many of the species present (including ash, maple, chestnut and some oaks) are poorly adapted to these disturbances, making them especially vulnerable. Many of these forests are found in a state of abandonment, with no silvicultural intervention in recent decades, after long periods of somewhat intense use.

**Case Study Description**: Two types of holm oak management are defined according to the degree to which accompanying broadleaf trees are present:

- in mixed holm oak stands (basal area of holm oak between 50% and 80% of the total), the aim is to maintain an adequate proportion of the species present, especially through the dissemination of regeneration cones adapted to each species's light requirements.
- In holm oak stands where the presence of other species is insufficient to qualify the stand as mixed (holm oak basal area superior to 80% of the total), the aim is to promote diversification by supporting broadleaf trees which are good seeders, generating openings for deciduous species and releasing advanced regeneration.

In both cases, the interventions encourage the individuals and species of valuable broadleaves, provided they are vigorous.

The interventions considered in the pilot holm oak stands include:

**Selective thinning**: the first step is to perform a selection of future crop trees (some 150 to 300 trees/ha, maximum 1/3 of the total density), primarily including vital and well-shaped valuable broadleaved trees, preferably from diametric class 15 and up but with time to grow, and also individuals with relevance for biodiversity conservation (underrepresented species, trees with relevant microhabitats, seed trees and fruit producers). In addition, occasional release and pruning may be considered for valuable broadleaved trees which fail to reach the aforementioned diameter if they show good vigour and robust, well-shaped trunks. Selective thinning consists in regulating the competition to which future crop trees are subject, eliminating their main competitors on the canopy level. The number of individuals to eliminate per future crop tree determines the intensity of the thinning: as a reference point, between 1 and 3 competitors are felled, with a lower value the more future crop trees selected and the more compressed their crown. As a guideline, the extracted basal area should not exceed 25-30%. The felled trees can either be extracted or kept in the soil, depending on their value. Another possibility is to girdle competitor trees instead of felling them to make the future crop tree's initiation of light exposure more gradual. The individuals close to the future crop trees not identified as competitors on the canopy level are maintained, thereby creating a service layer which supports the proper configuration of the selected tree and prevents the emergence of epicormic shoots. In the stands or sections of a stand which diverge from the optimal conditions for the application of MixForChange silviculture (simplified structure, very high density and/or limited or no layering), – which mixed (low and high) selective thinning could reach moderate or high intensity (up to 40% of the initial basal area or 50% of the initial density) – may be considered. In this case, selective thinning is combined with low thinning to reduce the density of the dominant layer in a more or less homogeneous way.

**Shoot selection (sucker cutback)**: intervention used to regulate competition on the tree level, applied on stumps with many shoots to concentrate growth in the best developed and positioned ones. The most common choice is to leave 1 or 2 shoots per stump, but the number may be increased to 3 if the holm oak or chestnut stumps present 8 to 10 living shoots. Thus,competition is reduced and vitality is improved on the stand level as well.

**Selective clearing**: partial elimination of the vegetation of the understory layer, based on a prioritization by height, species or vitality. Optionally, a range of total maximum shrub coverage to maintain may be established (more elevated, the more height the tree layer has and the less abundant the regeneration is) to reduce overall vulnerability to fires. In the demonstrative holm oak stands, it is common to see thickets of strawberry tree, heath and other woody species capable of achieving an arboreal aspect due to the availability of light after intense felling. In this case, selective clearing focuses on reducing these species' phytovolume, respecting thickets of sporadic species, with higher shade requirements and/or producers of flowers and fleshy fruit, due to their importance in biodiversity. In heath and strawberry trees of large development, a shoot selection is performed (leaving one or two shoots per stump) instead of cutting them completely, to limit posterior sprouting.

**Rejuvenation:** cutting misshapen individuals from valuable broadleaf species down to the ground in order to stimulate a new shoot which may be better shaped. The individual to be rejuvenated is typically young and must show sprouting capacity and favourable micro-site conditions. The individuals cut during rejuvenation may be extracted or left in the soil depending on their commercial value.

**Planting**: artificial regeneration of areas of low tree cover showing null or insufficient regeneration. A great diversity of species are planted, with densities between 10 and 250 trees/ha, taking advantage of the most favourable micro-sites and applying complementary planting techniques, such as individual shelters or soil conditioners, to augment success.

**Marking:** marking is performed in a part of the stand in a demonstrative way (training area), where the field crews who execute the interventions are accompanied and capacitated.

**Reference document**: Coello J, Piqué M, Beltrán M, Coll L, Palero N, Guitart L. 2022. Adaptive and close-to-nature management in mixed sub-humid Mediterranean forests: holm oak, chestnut, common oak and pine woods. Forest Science and Technology Centre of Catalonia, Solsona (Lleida, Spain); Forest Ownership Centre, Santa Perpètua de Mogoda (Barcelona, Spain). 104 p. (Language: English)

## 3.3. Spain (Girona) - Grazing systems to reduce wildfire severities

**Project**: Fire Flocks

**In brief**: Fire Flocks project promotes the contribution of herds to the risk management of fires through grazing in forest areas. The Fire Flocks seal promotes the continuity of the livestock activity in the territory and helps to prevent wildfires. Fire Flocks project brings together all public and private agents interested in the continuity of silvopastoralism, by aligning their various needs, and articulating a production and consumption chain of food products from herds with the added value of decreasing fire risk in woodlands with a strategic role in the propagation of wildfires (as determined by Firefighters of Catalonia and the Department of Agriculture).

**Website**: https://www.ramatsdefoc.org/en

**Location:** Girona

**Territorial context**: the project area is in the province of Girona, northeastern Spain. It is mainly composed of Aleppo pine with an understory of mastic and kermes oak, and the stands are dense, young and structurally similar.

**Traditional type of management**: the land ownership is all private (48 ha, 100 %). A shepherd can use their own land, or other land if they sign a lease agreement with the holders of the long-term forest tenure rights (typically 5 years). The land was abandoned about 15 years ago. Historically forests in the area were used to collect wood for individual purposes (at the farm or house level), and land was and still is made up of micro-private properties, with an average area of less than 1 ha. Before the forest was adapted to traditional pastoral regimes that included low intensity fires and the land cover was tolerant to natural fires caused by lightning

**Forest habitat or forest type**: *Pinus halepensis* forests (42.4 ha), *Quercus ilex forests* (1.5 ha), crops (2.8 ha), shrublands (0.9 ha), grasslands (0.2 ha)

**Aims**: the overarching objective of the project is to create fire resistant landscape through the continuity of extensive livestock farming. Thus, the specific objective is to graze the undergrowth forests and shrublands, as a means of reducing the amount of fuel (vegetation) within the forests and create open spaces between forested areas. The project aims to promote bioeconomy in rural areas, valorising the shepherd profession, the livestock, and the product from the livestock. The project aims to create a certification for products produced from the herds that are kept with the aim of contributing to the control of fire.

**Pressures/threats**: The reduction of traditional uses, mainly extensive livestock and multipurpose forestry (timber, woodfuel, charcoal or resins) has allowed regeneration of secondary vegetation characterised by proliferation of shrubby and bushy species. Moreover, the landscape has suffered a process of homogenisation with thousands of continuous hectares of highly fire-prone forests. These unmanaged forests are under an increasing vulnerability to wildfires because of climate change. A small number of wildfires are responsible for most of the burnt area (only 11 fires were accountable for 88 % of the surface burnt by 4800 fires in the last 8 years). These large forest fires represent a growing risk for society, as firefighting services are unable to face them, despite the high budgets and investments allocated.

The rural abandonment during the last century has allowed regeneration of secondary vegetation characterized by proliferation of shrubby and bushy species. Moreover, the landscape has suffered a process of homogenisation with thousands of continuous hectares of highly fire-prone forests

**Case Study Description**: Silvopastoralism can be a useful tool for the sustainable management of Mediterranean forests from a biological, social and economic perspective; in fact, the future of Mediterranean agroforestry is built on the recognition of its multifunctional role. Silvopastoralism is a common practice with high benefits for society (landscape conservation, fire risk management, and the production of high-quality meat and dairy) and reduces and controls the amount and continuity of the vegetation mainly from the surface layer. In the stands that have been abandoned for several years, with high amounts of fuel, a first intervention using mechanical treatments is usually required, in order to prepare the area and allow the entrance of the livestock. Subsequent to the initial mechanical intervention, grazing is a useful, and economically profitable, way of reducing the fuel loads.

The Fire Flocks programme seeks to reduce fuel loads and to break continuity of the vertical and horizontal vegetation layers. The predefined understory vegetation control targets are the following: (1) to graze 90 % of the annual biomass growth of the herbaceous layer, and (2) to graze 60 % of the annual biomass growth of the shrub layer. Thus, the aim is to create discontinuities (both vertical and horizontal) in the fuel loads.

For each shepherd, Fire Flocks designs a 5-year pastoral plan in which the number of animals and the number of grazing days per year are defined. The needs for feed supplements are also considered. With Fire Flocks, shepherds release their livestock in forests with predefined understory vegetation control targets. However, in comparison to grazing in open pasture, grazing in forests often carries additional effort and a reduction in herd productivity. The Artisan Butchers Guild of Girona counties works on adding value to the products of the participating farmers, through a label that certifies the herds' fire risk management tasks. Customers will thereby know that eating Fire Flocks products delivers social benefits, i.e. contributing to the ongoing viability of local extensive (rather than intensive) livestock farms, preserving forests, and reducing fire risk.

Wildfire management services identify woodlands that are strategic in fire propagation dynamics (SMP), and describe what results are expected through silvopastoralism, for an effective change in fire behavior in the area. Extensive livestock farms graze the SMP with their animals (sheep, goats or cows), following a grazing plan that will allow the aims of the plan to be achieved.

Butchers and restaurants sell meat and dairy products from flocks under the Fire Flocks label, and explain the added value behind them to their customers. Final customers become part of the fight against wildfires through the regular consumption of Fire Flocks products, and support the continuity of extensive livestock farming in our forests.

On one end, Fire Flocks is detailing the validation method which will certify performance of the grazing plan and allow shepherds to become part of Fire Flocks. The validation method must include field visits to certify the operations and assess factors according to observations and measures which will help the final decision on the grazing impact on the forest vegetation and, therefore, fire risk control. On the other hand, around 30 shepherds in Girona have expressed interest in being part of the Fire Flocks project. At the moment the project is working with them to: (a) select the grazing strategic areas, (b) define the grazing plan, and (c) list the butchers and restaurants where the products can be sold with Fire Flocks labels.

Together with the Artisan Butchers Guild of Girona counties, Fire Flocks is describing the regulations for the Fire Flocks label use. That will be the basis of the agreement between shepherds and butchers in relation to the use of Fire Flocks label.

**Reference document**: Krumm, F.; Schuck, A.; Rigling, A. (eds), 2020: How to balance forestry and biodiversity conservation – A view across Europe. European Forest Institute (EFI); Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Birmensdorf. 640 p. (Language: English)

### 3.4. Spain (Catalunia, Serra de Llaberia) - A case of local applied management of fire-prone ecosystems from northeastern Spain

**Project**: Management of fire-prone ecosystems

**In brief**: a public consortium (Consorci de la Serra de Llaberia) has managed the Natural Interest Area of Serra de Llaberia since 2004. The main objectives of the consortium are the preservation, revaluation, and multifunctional management of the area. The consortium is focused on: a) conservation and sustainable management; b) dissemination, promotion and education of the environmental interest of the area; c) social and occupational insertion, employment and training of people at risk of social exclusion; d) technical support to enable the municipalities (landowners, forest associations, city councils, and other entities) to access EU and national funds for the writing of scientific-technical documentation, and the technical direction of forest works; e) promotion and execution of actions for wildfire prevention; f) providing facilities and information to visitors.

**Website**: https://www.serrallaberia.org/

**Location:** Catalonia, Tarragona

**Territorial context**: Serra de Llaberia is a mountain range, in the Province of Tarragona, northeastern Spain. The range is named after the village of Llaberia. The area is included in the Natura 2000 site Tivissa-Vandellòs-Llaberia (ES5140009) and occupies 10 350 ha, ranging from 181 m to 915 m altitude. This Mediterranean area has a climatic gradient, between a maritime xero- thermic and continental xerothermic climate, with hot summers and mild winters, an annual average temperature of 13 °C and a mean annual precipitation around 650 mm. The parent material is composed of limestones and clays of Jurassic and Triassic rocks, with poorly developed soils. The main forest formations are represented by stands of young, dense, and homogeneous Aleppo pine (*Pinus halepensis*) and holm oak (*Quercus ilex*). There are also remnants of Pyrenean black pine (*Pinus nigra subsp. salzmannii var. pyrenaica*) and quejigo oak (*Quercus faginea*) forests from the traditional-pastoral regimes that included low intensity fires with tolerance to natural fires caused by lightning.

**Traditional type of management**: the area is managed by a public consortium (Consorci de la Serra de Llaberia) created in 2004. In 2009 the consortium created a private forestry enterprise (enterprise of the environmental service of the Serra de Llaberia). This enterprise executes the main forestry works that the consortium plans and is also used by other public and private entities and companies. The land ownership is mainly private (7674 ha, 74 %) and most of them are small properties (less than 10 ha). Public lands represent just 11 % of the land (1108 ha) and are owned by the councils and Catalan government. There are also 1567 ha (15 %) of private land that are currently managed by custody agreements. The area was used for agriculture (principally olive trees, hazelnuts and vines) and other traditional uses, mainly extensive livestock, and multipurpose forestry. Historical fire used by shepherds was the main source of low and medium intensity fires until the twentieth century, and created open forest stands of Pyrenean black pine, stone pine (*Pinus pinea*) and quejigo oak.

**Forest habitat or forest type**: *Pinus halepensis* forests (4731 ha), *Quercus ilex* forests (772 ha), *Pinus nigra* forests (173 ha), *Quercus faginea* forests (120 ha), *Pinus pinea* forests (18 ha), broadleaved species forests (19 ha), shrublands (2548 ha), grasslands (213 ha), abandoned crops (122 ha)

**Aims**: the main objectives are the preservation, revaluation, and multifunctional management of the Natural Interest Area of Serra de Llaberia.

**Pressures/threats**: the landscape has been strongly modified as a result of land-use changes and sequential abandonment of agricultural land throughout the twentieth century, starting from 4 % forest cover at the beginning of the twentieth century to 89 % nowadays. The abandonment of the terraced sites formerly used for agriculture (principally olive trees, hazelnuts and vines), which protected the soil and preserved the natural vegetation in the recent past, have been progressively removed, causing important land degradation problems. The reduction of other traditional uses, mainly extensive livestock, and multipurpose forestry (for timber, woodfuel, charcoal or resins) has allowed a secondary vegetation regeneration characterised by bush proliferation. Moreover, the landscape has experienced a process of homogenisation with thousands of hectares of continuous highly fire-prone forests. After the mid-1950s, with rural abandonment and depopulation, the fire regime changed to high intensity. The area has suffered several large wildfires in the last decades. Recent fire activity has slowed down because of the efforts of the fire service and forest management. However, in spite of these efforts fuels continue to accumulate in forests, and consequently there is a continuing risk of large forest fires.

**Case Study Description**: The management of the area is looking to reduce the vulnerability in front of wildfires and to achieve a better adaptation and resilience to aridity caused by climate change.

**Forest management** is focused on the objective of creating more mature structures, concentrating biomass on the wood of trees and not on fine fuel. This, along with lower degrees of vertical and horizontal continuity of the sands, increases the chances of forest stands surviving fires and allowing them to develop into old growth stands of open forest that had been typical of the area, and which are critical for the maintenance of diversity in the area. All the treatments are done to allow the final cutting to be delayed. Over the last five years criteria for **maintaining deadwood** in the forest have also been considered for conservation purposes, before there was no technical criteria to leave deadwood on the site or to generate new deadwood for species conservation. The treatments applied in the area follow regional guidelines and **silvicultural models for sustainable forest management (ORGEST)** (Piqué et al. 2014) and provide practical, applicable, and updated information to forest managers at an operational level. The area has been pioneering in its use of **prescribed burning** (the planned and precise application of low intensity fire) as a management tool. Prescribed burning can be used to limit the slope of large forest fires as part of pre-extinguishing and prevention plans, as well to emulate natural processes that allow for maintenance of ecosystem biological capacity. The execution of the prescribed burns is carried out based on pre-established objectives: to protect the ecosystem from the risk of devastating fires, restore and improve fauna and flora habitats, and management of forest.

**Forest management and fire prevention**. The consortium has developed forest planning for the whole area which has allowed prioritisation of the actions depending on the fire prevention efficiency. It has also identified the Strategic Management Points (SMPs); SMPs are bands of low fuel or auxiliary bands anchored to paths that allow the resources for extinguishing large fires to be concentrated more safely and efficiently. Another important activity related to both forest management and fire prevention is the **production of local biomass for local consumption**. Recently a new district heating for public buildings has been planned in Tivissa and the consortium will supply it with locally and sustainably managed biomass from SMPs. With the same objective, the consortium coordinates a network of landowners and local entities to prioritize action for fire prevention and maintenance of water points for the fire extinction service.

**Extensive local livestock**. The consortium has also enhanced the habitat for a local goat breed (Cabra Blanca de Rasquera), maintaining open spaces and other features they need (water pools and tracks). The consortium has also worked with the national fire shepherds' school to improve the conditions for the local shepherds and help the new young shepherds. In this sense, the consortium is involved in the projects Open2preserve and FireShepherds, which both aim to introduce extensive silvopastoralism as a measure to prevent forest fires and to promote production of local forest products.

**Social tasks**. The consortium, with the support of a specialized company of training and work, provides participants with help getting a job. The participants must follow a two-year programme and are professionally trained in forestry operations. Later, they can perform tasks, such as the maintenance of the path network, prevention of forest fires, and conservation of habitats in wetlands. They also restore stone structures from the national heritage. They are guided by the technical personnel of the consortium and are always accompanied by a foreman.

**Cultural tasks.** The consortium works in the conservation of the cultural heritage of the area. It improves and maintains the historical path network and restores and maintains the drystone elements such as the retaining walls for terracing, cobblestoned paths, lime kilns, and other unique elements constructed using this technique.

**Reference document**: Krumm, F.; Schuck, A.; Rigling, A. (eds), 2020: How to balance forestry and biodiversity conservation – A view across Europe. European Forest Institute (EFI); Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Birmensdorf. 640 p. (Language: English)

## 3.5. Spain (Catalunia, Poblet) - Stand dimostrativi per la gestione forestale per l'adattamento ai cambiamenti climatici

**Project**: CANOPEE - Climate monitoring maps and adaptive management in a changing climate

**In brief**: Project CANOPEE is the result of a broad collaboration between Spanish, Andorran and French forestry technicians and researchers and aims to provide specific responses to the effects of climate change on Pyrenean forests and their adaptation possibilities. In this context, the Project aims to: 1) Strengthen and extend monitoring of the phenology of the main Pyrenean forest species, 2) Develop a tool to characterise the viability of trees in the Pyrenean mountains and their vulnerability to climate change, 3) Map the distribution and vulnerability (current and future) of the main Pyrenean forest species under different climate change scenarios, 4) Develop and implement adaptive management actions to minimise expected impacts

**Website**: Canopee

**Location:** Poblet (Tarragona, Catalunia)

**Territorial context**: The stand is located in a closed basin of 45 hectares, with a moderate-to-high average slope (about 30 per cent) and a north-west (NW) orientation. The altitude is between 640 and 1080 m. The climate is typically Mediterranean, although with a tendency towards continental. The general orientation of the forest, towards the north, influences the climate.

**Traditional type of management**: The Barranc de la Teula basin was intensively managed for decades and subsequently ceased to be managed. As a result, there is currently an aged stand, with low vitality, abundant regrowth and low diameters (abundance of non-inventory trees)

**Forest habitat or forest type**: mixed stand of holm oak and strawberry tree accompanied by laburnum, oak, maple and other species.

**Aims**: Achieving a forest stand that is better adapted to the progressive increase in aridity and to the greater recurrence and intensity of extreme phenomena (such as drought, fire or pests) resulting from climate change through 1) the reduction of competition, thus improving vitality and water status (greater efficiency in water use) 2) conservation and enhancement of biodiversity, including the promotion of drought-adapted species and individuals from seed (improved genetic diversity); 3) medium-term reduction of vulnerability to fire by reducing vertical continuity and biomass volume. The action should also improve the water balance in the basin (increasing blue water) by reducing evapotranspiration and increasing infiltration and surface runoff.

The **operational aims** consist of moderate deforestation, with an impact mainly on non-inventory trees. From 4,000 trees/ha to about 2,000 trees/ha, without removing more than 30% of the basal area or reducing canopy cover below 70%. Another operational objective is to respect the initial holm-oak-arboreal ratio, accompanying species and trees with singularities.

**Pressures/threats**: Climate change is likely to make the multifunctionality of the Pyrenean forests much more difficult, causing the decline of certain productive or protective stands, significant alterations to habitats of interest and the deterioration of the landscape and forest environment. For this reason, it is increasingly evident that forest managers in the Pyrenees must anticipate these changes, jointly developing tools to improve knowledge and help decision-making in the implementation of adaptation actions in the territory.

**Case Study Description**: In order to assess the initial situation of the forest stand, the result of the intervention and the evolution of the stand over the years, a permanent test plot was established within the stand (8.9 ha) and another in the control area (stand with the same characteristics, but where no intervention was carried out). Both test areas are circular and have a radius of 15 m. In the area of the second felling phase (11.8 ha), a further 3 inventory test plots were established (2 of radius = 5m and 1 of radius = 8m). The vegetation was characterised by measuring the basal area, the diameter of all trees with a diameter > 2.5 cm (and height > 130 cm) per species, the count of trees with a diameter < 2.5 cm (and height > 130 cm) per species, the number of stump trees, the average cover and height of shrub species, and the cover of herbaceous species.

Two methodologies were applied to study the water balance of the basin:

- Application of the MEFDFATE theoretical model with detailed soil characterisation: orientation, slope, lithology (and soil classification), profile and average soil depth. In the profile elaboration, 4 levels were created, reaching a depth of 80-100 cm. The texture, stoniness and bulk density were described for each level.
- Direct flow measurements were made by measuring the basin in question and a 'twin' control basin. These measurements were carried out over the last 20 years by the University of Alicante, which will provide information on time series and post-intervention monitoring.

The pre-intervention dendrometric characteristics are as follows:

| | Densidad (pies/ha) | AB ($m^2$/ha) |
|---|---|---|
| *Quercus ilex* | 2766 | 24,72 |
| *Arbutus unedo* | 672 | 6,54 |
| *Phyllirea latifolia-media* | 101 | 0,68 |
| *Quercus cerrioides* (humilis x faginea) | 3 | 0,06 |
| TOTAL pies inventariables (diámetro>7,5 cm) | **3575** | **32,20** |
| TOTAL pies no inventariables (diámetro < 7,5 cm) | **4341** | **8,99** |
| **PIES TOTALES** | **7379** | **41,19** |

| | |
|---|---|
| Densidad cepas (cepas/ha) | 2403 |
| Media pies por cepa (pies/cepa) | 3,85 |
| Máximo de pies por cepa (pies/cepa) | 16 |

The pre-intervention canopy cover fraction was about 85%, the average diameter was 10.7 cm and the average height was 6.25 metres. The shrub cover was very low. In the areas with the highest canopy cover, this was about 8% and the main species present were heather and broom. In the slightly more open areas, genista dominated, with a cover of up to 20%. The herbaceous cover was also low, ranging between 10 and 40%, consisting mainly of grasses and mosses.

**Quantitative characterisation of the interventions**: in order to reach the prefixed aims, a net reduction was planned (according to the ORGEST model reference Qii06), concentrating mainly on non-inventory trees (CD5) and respecting the existing holm oak to arbutus ratio.

The intervention involved the removal of 53% of the initial trees, specifically 964 trees/ha (DC≥10) and 2,512 non-inventory trees/ha (DC5). The impact of the intervention is 23% of the initial basal area (AB), leaving a final AB of 25.7m$^2$/ha. The final canopy cover is 75%. The action made it possible to reduce the high initial competition without opening up the canopy cover. The mixed stand structure was also maintained (respecting the accompanying species), and an attempt was made to create a structure that is not very vulnerable to large forest fires.

**Effect of the intervention on the water balance**: the intervention would lead to a reduction in the leaf area index (LAI) from 6.92 to 5.17 m2 , mainly due to the reduction in the number of trees. The water balance consequences predicted by the model include an increase in water withdrawn from 136 to 172 mm/year on average. On the other hand, the model predicts a reduction in the duration of the drought stress period, from 126 to 101 days/year. 101 days/year, on average, for *Quercus ilex* and *Arbutus unedo*.

**Final evaluation of the intervention**: the felling intervention has reduced competition, allowing a greater availability of resources for the remaining trees. It is expected that the improvement in stand viability will be reflected in the medium to long term in an increase in wood volume (growth in diameter and height), which will lead to greater carbon fixation on an individual level. At the same time, maintaining a high canopy cover is expected to control regrowth (an undesirable effect, since the aim is to obtain a regular structure that is less vulnerable to large fires and to promote larger, monopodial stands). The results of the application of the MEDFATE theoretical model seem to indicate that the action increased both the water available for vegetation and the water leaving the basin in the short term, since the initial interception was significantly reduced. With regard to the actual impact observed on the flow rates, measurements of the flow rates out of the basin in question compared to those of the control basin (both measured) will make it possible, in the coming years, to assess the changes produced by the action. Finally, the silvicultural treatment preserved the initial biodiversity, maintaining the species initially present and preserving trees with singularities (large trees, trees with microhabitats and dead wood). Once the felling remains have been reduced (in the next few years), this will result in a structure that is not very vulnerable to large fires.

**Reference document**: Baiges Zapater T; Camarero Martinez JJ; De Cáceres M; Cazals P; Cantero Amiano A; Cervera Zaragoza T; Coll L; Delpi R; Komac B; Martin S; Navarro Perez De Pipaón L; Palero Moreno N; Pargade J; Rouyer E; Villiers T, 2019. CANOPEE - OPCC. Guía de gestión forestal para la adaptación al cambio climático de los bosques pirenaicos. 128 p. (Language: Spanish)

### 3.6. Spain (Paesi Baschi, Vitoria - Álava) - Stand dimostrativi per la gestione forestale per l'adattamento ai cambiamenti climatici

**Project**: CANOPEE - Climate monitoring maps and adaptive management in a changing climate

**In brief**: CANOPEE Project is the result of a broad collaboration between Spanish, Andorran and French forestry technicians and researchers and aims to provide specific responses to the effects of climate change on Pyrenean forests and their adaptation possibilities. In this context, the Project aims to: 1) Strengthen and extend monitoring of the phenology of the main Pyrenean forest species, 2) Develop a tool to characterise the viability of trees in the Pyrenean mountains and their vulnerability to climate change, 3) Map the distribution and vulnerability (current and future) of the main Pyrenean forest species under different climate change scenarios, 4) Develop and implement adaptive management actions to minimise expected impacts.

**Website**: Canopee

**Location:** Vitoria/Gasteiz, Alava (País Vasco)

**Territorial context**: The stand under intervention is located in public utility forests in villages to the west of the municipality of Vitoria (Álava). The municipality of Vitoria is the third largest municipality of holm oak forests in the Basque Country. The stand is located on a moderate slope (10-20%), facing north (N). The altitude varies between 620-690 m.

**Traditional type of management**: The stand is representative of large continuous expanses of holm oak (*Quercus ilex*) in the Sierra de Badaia, resulting from past coppicing treatments. These stands have currently ceased to provide timber and firewood since the 1950s and 1960s. They are capitalising on their timber stocks, occasionally providing firewood, locally, in the most accessible areas.

**Forest habitat or forest type**: Holm oak stands, with the occasional presence of juniper.

**Aims**: regulate competition between holm oak shoots for water resources and thus increase stand viability, 2) promote stand diversification, 3) reduce stand evapotranspiration and improve the water balance by increasing infiltration and water quantity.

**Pressures/threats**: climate change is likely to make the multifunctionality of Pyrenean forests much more difficult, causing the decline of certain productive or protective stands, significant alterations to habitats of interest and the deterioration of the landscape and forest environment. For this reason, it is increasingly evident that forest managers in the Pyrenees must anticipate these changes, jointly developing tools to improve knowledge and aid decision-making in the implementation of adaptation actions in the territory. In the present case study, the poor initial conditions of these trees, generated by centuries of *recepado*, mean that their growth is moderately low, with little or no fructification and a low capacity to respond to disturbances (attacks by biotic agents, drought, snowfall, etc.).

**Case Study Description**: The operational aims consist of carrying out a mixed selective thinning treatment: 1. Reducing the density of holm oak shoots; 2. Clearing the undergrowth; 3. Manual thinning and cutting of holm oak shoots extracted for energy use (firewood).

Based on the baseline data, a representative plot of holm oak was chosen to be cut for firewood for local use in early 2018. A neighbouring control plot of the same size and forest aspect was also chosen in order to assess future changes. For the quantitative assessment of the treatment characteristics, an inventory was carried out to compare the pre- and post-intervention conditions of both the intervention sub-plot and a non-intervention control sub-plot. In each of these, a test plot of approximately 15 x 15 m was set up, in which the following were measured before and after treatment: basal area, species and diameter of all trees with DBH > 5 cm, the cover (%) and mean height of each shrub species, and the cover (%) per biological group of herbaceous species (grasses and non-grasses). For each species, trees with DBH < 5 cm were also counted, distinguishing between those with a height > 130 cm and those with a height < 130 cm.

The intervention had a significant effect on the tree layer, which in the test area was composed exclusively of *Quercus ilex*. The density of this species decreased from 2,894 to 1,180 trees/ha, a reduction of 59.2%. The effect on the basal area was also considerable, falling from 30.6 to 15.14 $m^2$/ha, a reduction of 50.5%. Following the intervention, the average diameter increased from 11.6 to 12.5 cm .

**Effect of the intervention on the water balance:** a water balance simulation was carried out using the Medfate model. According to the water balance model, the intervention would lead to a reduction of the leaf area index (LAI) from 4.21 to 2.07 $m^2/m^2$. The water balance consequences predicted by the model include an increase in water exported from 265 to 459 mm/year on average. On the other hand, the model predicts a reduction in the duration of the drought stress period from 88 to 20 days/year on average for *Quercus ilex*, although this estimate does not take into account growth after the intervention.

**Effetti degli interventi**: Effects of the interventions: the application of the mixed selective regeneration treatment resulted, on the one hand, in a significant reduction in density and thus in competition in the upper layer. On the other hand, the density of dominated and subjected holm oak shoots (inventoried as young) was reduced more significantly, thus achieving an overall improvement in stand vigour. The treatment also favoured stand diversification. Not only were all individuals respected with improved appearance and vitality, but the conditions for their development were improved due to the elimination of competition around each individual, including the removal of scrub. Future evaluation of the interventions will be followed, in principle, by two methods:

Direct measurements of trees. Several growth sensors, or dendrometers, were installed at the standard height of 130 cm on representative trees in each plot and with an average diameter, both in the thinned plot and in the control plot. The aim is to be able to assess the diametric growth of these trees at any time, which may vary from plot to plot, not only as a function of competition from neighbouring trees, but also of climatic conditions or the presence of disturbances. The point measurements of these dendrometers can be correlated with more precise automatic sensors that measure continuously throughout the year, and which are installed on a holm oak tree in Arkaute, a few kilometers from the intervention area.

Remote Sensing. Various web tools or viewers based on the free Sentinel 2 and Landsat satellite images are available in HAZI. These tools allow, both numerically and visually, continuous monitoring of the phytosanitary status, phenology and vigour of any plot or tree stand.

- data and image comparator

- Generator of animations from multitemporal images

**Reference document**: Baiges Zapater T; Camarero Martinez JJ; De Cáceres M; Cazals P; Cantero Amiano A; Cervera Zaragoza T; Coll L; Delpi R; Komac B; Martin S; Navarro Perez De Pipaón L; Palero Moreno N; Pargade J; Rouyer E; Villiers T, 2019. CANOPEE - OPCC. Guía de gestión forestal para la adaptación al cambio climático de los bosques pirenaicos. 128 p. (Language: Spanish)

# 4. PINE FORESTS - Habitat 9530* (Sub-) Mediterranean pine forests with endemic black pines

## 4.1. Spain (Catalunia) - Adaptive and close-to-nature management in pine stands

**Project**: LIFE MIXFORCHANGE (LIFE15 CCA/ES/000060) - Innovative management strategies for adapting mixed sub-humid Mediterranean forests to climate change

**In brief**: The main objective of the project is to contribute to the adaptation and greater resilience of mixed sub-humid Mediterranean forests to climate change, favouring their conservation and the maintenance of their productive, environmental and social functions. Specifically, the project aims to: i) develop and implement innovative forest management techniques, which allow forests to adapt to climate change and improve ecological and economic value in the medium term; ii) develop new tools to integrate the adaptation of sub-humid Mediterranean forests to climate change into the policy and laws on forest management; iii) develop new tools to strengthen the economy linked to the products provided by these forests, preventing or reversing their abandonment; iv) transfer the tools and techniques developed and results obtained taking into account the main stakeholders (forest owners, technical staff and public administration) at a regional, national and European level, and raise social awareness on the challenge of adapting forests to climate change.

**Website**: www.mixforchange.eu

**Location:** Catalonia

**Territorial context**: the project activities have been implemented in 197 ha of mixed forest in the Catalan sub-humid Mediterranean, in four geographical areas in northeast Spain. The four areas where pilot demonstration stands were located are:

- Montnegre-Corredor: Littoral low mountain conditions (maximum altitude 760 m, distance to sea <10 km), warm temperatures and high precipitation (Foëhn), steep slopes, densely populated. Silica substrates.
- Montseny: Pre-littoral high mountain conditions (maximum altitude 1700 m, distance to sea 20-40 km), low winter temperatures and high precipitation (Foëhn), steep slopes. Silica substrates.
- Bellmunt-Collsacabra: Continental Mediterranean mountain conditions (maximum altitude 1300 m, distance to the sea> 50 km), low winter temperatures and medium precipitation, high slopes. Silica and calcareous substrates.
- Ripollès: Conditions of continental Mediterranean mountain, in transition to eurosiberian from Pyrenees (altitude maximum 1500 m, distance to the sea> 50 km), low temperatures in winter and average precipitation, high slopes. Silica and calcareous substrates.

**Traditional type of management**: Conventional forest management or no silvicultural intervention in recent decades, after long periods of somewhat intense use.

**Forest habitat or forest type**: Mediterranean pine forests

**Aims**: the interventions' general aim is to promote the stands' resistance and resilience in the face of the main impacts of climate change, in a way which is compatible with economic and ecological sustainability in the medium and long term. In particular, the management of pine stands seeks to generate

and maintain diversified structures in terms of layers and species, with a high presence of oaks and other broadleaf species. Pines are maintained in the most favourable locations where they do not impede the development of the rest of the species. The aim is to accompany the broadleaves' development and the progressive change of dominance of the pine canopy.

**Pressures/threats**: sub-humid Mediterranean forests of great environmental, productive and social interest are subject to threats that jeopardize the provision of many of these ecosystem services. Although the stands are, in general, mixed and show a certain degree of stratification, the prevailing form of management has progressively led them to a certain point of structural and species simplification. The pine stands often show an advanced senescence process. Mixed pine and broadleaf forests tend to be structured as a canopy of pines (species promoted in the past) with a broadleaf sub-canopy layer. urrently, the broadleaves show a vigorous development, and the pine layer appears capitalised and aged, its regeneration limited by the high density of broadleaves. The main threat posed by climate change in this context is the rise in the intensity of droughts and forest fires. Many of the species present (including ash, maple, chestnut and some oaks) are poorly adapted to these disturbances, making them especially vulnerable. Many of these forests are found in a state of abandonment, with no silvicultural intervention in recent decades, after long periods of somewhat intense use

**Case Study Description**: in stands with a low-density tree cover and too few broadleaves to generate a full layer, enrichment plantings may be executed, introducing and reinforcing the target broadleaves and pine trees in favourable sites. In the interventions, valuable broadleaf individuals and species are promoted, provided they show high vigour.

The structure pursued with MixForChange silviculture in pine stands varies according to the vitality and regeneration capacity of the upper pine layer and the broadleaf sub-canopy layer:

<u>Pines with little vigour and in a phase close to senescence, fully established broadleaf sub-canopy with a capacity to develop</u>: small-scale heterogeneity is promoted (individual trees or patches, depending on the species' temperament), accompanying the progressive substitution of the dominance of pine. They tend to be zones in which the broadleaf layer shows strong development, whether due to the high site quality or the deficient coverage of the pines canopy caused by their loss of vitality (advanced age, effect of recurring droughts) or the previously applied management techniques.

<u>Vigorous pines with the capacity to regenerate and/or not-yet-consolidated broadleaf sub-canopy layer</u>: heterogeneity is promoted by patch or copse, regulating competition in the upper canopy and between this canopy and the broadleaf sub-canopy layer to accompany the stand's progressive development.

Depending on the stand conditions the interventions are adjusted to advance, through a variable number of interventions of adaptation or transition, towards the final desired structure. When the structure meets the general targets pursued (vertically and horizontally heterogeneous, with regeneration processes, adequately shaped future crop trees, an adequate level of capitalisation of the various species) the conditions are maintained through selection felling, that is, selective thinning on trees of all sizes.

The interventions considered in the demonstrative pine stands include:

**Selective thinning**: the first step is to select some 200 to 400 future crop trees/ha (fewer the larger the proportion of broadleaves selected and tree size), regardless of total density. These future crop trees mainly include vital, well-shaped pine trees or valuable broadleaved species, preferably of diameter class 15 and up but with time to grow, and also individuals important for biodiversity conservation (underrepresented species, trees with microhabitats of interest, seed trees and fruit producers). In addition, occasional release and pruning may be considered for valuable broadleaved trees which fail to reach the aforementioned diameter if they show good vigour and robust, well-shaped trunks. Selective thinning consists in regulating the competition to which future crop trees are subject, eliminating their main competitors on the canopy level and also on the root level if the future crop tree is a pine. Future crop trees tend to form part of the dominant layer, which is why selective thinning is frequently applied to regularise structures. The number of trees to eliminate per future crop tree determines the thinning intensity: as a guideline, between 1 and 3 competitors are felled, with a lower figure the more future crop trees selected, the more compressed their canopy and the more tolerant to shade their behaviour is. As a general rule, the extracted basal area does not exceed 20-25%. The felled trees can either be extracted or kept in the soil, depending on their value. Another possibility is to girdle competitor trees instead of felling them to make the future crop tree's initiation of light exposure more gradual. The individuals close to the future crop trees not identified as competitors on the canopy level are maintained, thereby creating a service layer which supports the proper configuration of the selected tree and prevents the emergence of epicormic shoots. In the stands or sections of a stand which diverge from the optimal conditions for applying MixForChange silviculture (simplified structure, very high density and/or limited or no stratification), may mixed selective thinning be considered to potentially achieve moderate intensity, with a maximum extraction of 35% of the initial basal area. Selective thinning is combined with low thinning, seeking to reduce the high density of the dominated layer, more or less homogeneously throughout the stand, and the development of the more adapted and vigorous trees is favoured, with the goal of maintaining, in the long term, a stable, vital cover advancing toward capitalisation.

**Shoot selection (sucker cutback)**: intervention used to regulate competition on the tree level (sprouting species) which is applied on stumps with many shoots to concentrate growth in the most well developed and positioned ones, generally 1 or 2 per stump. It is a typical intervention on species with high sprout capacity, like holm oak and chestnut, which are cut intensively, cutting more than half of the living shoots from each stump, while in oak and maple it is applied with less intensity. Thus, competition is reduced and vitality is improved on the stand level as well.

**Selective clearing**: partial elimination of the vegetation of the understory layer, based on a prioritisation by height, species or vitality. Optionally, a total target coverage range may be established to reduce overall vulnerability to forest fires. In pine stands which have had a sparse tree covering for a long time, a developed undergrowth layer is typical, with an abundance of light-demanding species. In this case, the phytovolume of these species is reduced in an intense way, respecting some individuals from sporadic species with higher shade requirements and/or producers of flowers and fleshy fruit, due to their importance for biodiversity. In the case of heath, strawberry tree and boxwood shrubs, it is advisable to perform a selection of shoots (leaving 1 or 2 shoots per stump) instead of cutting all the shoots, to limit posterior sprout.

**Rejuvenation**: in the stands with a great abundance of young broadleaves, one possibility to consider is felling poorly shaped trees to generate a new shoot. The individual to be rejuvenated is typically young and must show sprout capacity and favourable micro-site conditions. The individuals cut during rejuvenation may be extracted or left in the soil, depending on their commercial value.

**Planting**: artificial regeneration in the best micro-sites, adapting the species choice to them and using complementary techniques to increase success, including individual shelters or soil conditioners. If the tree cover is sparse due to intense disturbances, one option may be to prioritise frugal conifers (maximum planting density of 400 trees/ha), which during their development will create the conditions for the establishment and consolidation of a new cohort of broadleaves requiring initial accompaniment. Broadleaves may also be planted (10-150 trees/ha) to enrich stands where they are scarce.

**Sanitary felling**: in areas affected by biotic or abiotic damage, a portion of the dead or dying trees, with symptoms of disease or pests, affected by snowfall, wind, hail, etc. are eliminated.

**Marking:** marking the future crop trees and their competitors to fell is performed throughout the stand. The field crews who execute the tasks are regularly accompanied and capacitated.

**Reference document**: Coello J, Piqué M, Beltrán M, Coll L, Palero N, Guitart L. 2022. Adaptive and close-to-nature management in mixed sub-humid Mediterranean forests: holm oak, chestnut, common oak and pine woods. Forest Science and Technology Centre of Catalonia, Solsona (Lleida, Spain); Forest Ownership Centre, Santa Perpètua de Mogoda (Barcelona, Spain). 104 p. (Language: English)

## 4.2. Spain (Catalunia) - Conservation and enhancement of old-growth forest of Pinus nigra laricio

**Project**: LIFE+ Pinassa (LIFE13 NAT/ES/000724) – Sustainable management for the conservation of black pine forests in Catalonia

**In brief**: LIFE+ Project Pinassa has as its main objective to improve the conservation status of larch pine forests (habitat 9530* - (sub)Mediterranean endemic black pine forests) in Catalonia. To this end, the Project proposes actions aimed at the main problems and threats that this habitat faces, in 10 Sites of Community Interest (SCI). The conservation actions are based on the following specific aims:

- To improve larch pine stands stability, regeneration conditions, biodiversity status and decrease vulnerability to forest fires
- To increase the resistance and resilience of larch pine forests to forest fires and climate change
- Elaborate management plans to make forest conservation compatible with its productive and recreational use
- Disseminating information about the Natura 2000 network, the importance of the environmental value of these areas and their sustainable management.

**Website**: http://lifepinassa.eu/?lang=es

**Location:** Catalonia

**Territorial context**: of the area covered by the habitat 9530* in Catalonia, 23,058 ha (35%) are included in 28 Special Areas of Conservation of the Natura 2000 network. For the implementation of measures to improve the structure of mature larch pine forests, 3 areas were chosen between the Pre-Pyrenees and Southern Catalonia, included in 3 SACs for a total of 41.33 ha. In addition, a further 132.79 ha of mature larch pine forests were identified for natural evolution.

**Traditional type of management**: The slopes covered by larch pine forests in Catalonia were formerly used for grazing and timber production, activities that favoured the development of open woodland structures that allowed shady pastures to be maintained in a Mediterranean mountain climate, with green, desirable grass for longer. For this reason, the larch pine habitat has always been favoured on mid-mountain slopes in Catalonia and has never disappeared in the Els Ports, Tivissa-Vandellòs and Llaberia areas. However, with the socioeconomic changes that took place in the 20th century, these activities, and more generally the economic activities linked to the rural context, were abandoned, causing a progressive densification of the larch pine stands and a change in their structure with the growth of certain oak species in the dominated plane. These processes are considered to be one of the causes of the large forest fires that occurred in the 1990s in Catalonia, most of which affected larch pine forests.

**Forest habitat or forest type**: 9530*

**Aims**: Identifying old-growth larch pine forests for natural evolution in order to protect their distinguishing characteristics of naturalness and maturity. Moreover, through silvicultural interventions, the aim is to improve their structural stability and ensure the short and medium-term conservation and regeneration of larch pine stands that have the potential to become ancient forests.

**Pressures/threats**: The mature larch pine forests in which the interventions were carried out presented problems of stability, lack of structure heterogeneity, poor regeneration and lack of regulation of public use.

**Case Study Description**: Per poter definire un bosco vetusto come tale, si può ricorrere a due tipi di valutazione: una prima analisi qualitativa che permette di valutare rapidamente se un popolamento soddisfa i criteri di maturità adeguati, e un inventario quantitativo che permette di quantificare le caratteristiche strutturali del popolamento per poterlo confrontare con altri.

**Qualitative stand analysis:** A representative transect of the stand is carried out to observe its characteristics. If the stand has an area of less than 1 ha, the assessment is carried out over its entire extent, taking into consideration the areas where the forest is most mature. Several indicators are used to describe the stand, corresponding to the main naturalness characteristics associated with mature forests, and a score is assigned to each of them. In order to be defined as a 'mature forest', the stand analysed must reach a previously established minimum total score. The main indicators to be evaluated in this phase are listed below.

A) Basic stand characteristics: Location, UTM coordinates of a central point of the stand, approximate area; brief description of the forest, indicating the main tree species, accompanying tree species and typical shrub and herb species of the plant community.

B) Structural indicators:

- number of tree species and their degree of cover;
- Structural diversity: indicate whether the structure of the forest is regular (90% of the individuals belong to the same age class), semi-regular (90% of the individuals belong to two consecutive age classes), irregular (all age classes are present in the stand, or at least 90% of the individuals belong to three consecutive age classes) or *adehesada* (stand consisting of large trees, often of low bearing size and dispersed in space).
- Standing deadwood. From recently dead tree specimens to broken trees (snags), from a diameter of 17.5 cm.
- Laying deadwoods. Logs or large branches with a diameter at half their longitude greater than 17.5 cm.
- Living trees with the presence of microhabitats.
- Degree of coverage of openings in the crown layer, created by the fall of trees due to natural disturbance or fire. Openings due to the discontinuity of the horizontal structure of the forest or the presence of rocky outcrops are not considered.
- Tree species cover with a height > 10 cm and a diameter of less than 2.5 cm. Recently germinated and not yet established seedlings are not considered.
- Advanced regeneration. Degree of cover of tree species of diameter class 5.

**Quantitative stand analysis**: quantitative inventories are to be carried out in permanent circular test plots with a radius of between 15 and 25 m (Fig. 1, attached 'Schematic representation of a circular test plot'. The inventory of live specimens is carried out in concentric radii. From EUROPARC-España 2017). The size of the LDAs should be adapted to the size of the forest (they should cover between 5 and 10% of the stand area).

The main indicators to be quantified at this stage are listed below.

A) Naturalness indicators:

- number of native tree species present

- basal area
- number of diametric classes of living trees, starting from the DBH of 17.5 cm
- Dominant height of the most abundant species or two in terms of basal area
- Volume of living trees (value per hectare), considering only specimens with a normal diameter # 17.5 cm
- Number of vertical layers: bottom layer (< 1/3 of dominant height); middle layer (between 1/3 and 2/3 of dominant height); top layer (> 2/3 of dominant height). Each individual vertical layer must have a degree of coverage > 20% in order to be defined as such.
- Number of exceptionally large trees (3 times the diameter of the dominant height of the stand).
- Volume of dead wood on the ground and standing (m3/ha) considering trunks with a diameter > 17.5
- Living or dead trees with microhabitat (N specimens/ha)
- Number of seedlings and advanced regeneration (N seedlings/ha)
- Specimens of diameter classes 10 and 15 (N specimens/ha)
- Silvogenetic phases identified in the stand in percent.
- Biodiversity. Species of flora and fauna identified and classification of these into exotic, threatened or bioindicator.

B) Signs of human intervention: description of the indicators of cultural elements in the population, depending on whether they date back to before the first complete aerial photograph or are recent (after 1946 or 1956 to the present).

- Temporal continuity. Evaluation of the population structure over time through the use of historical archives, forestry plans, aerial photographs.
- Agricultural-pasture uses. Identified by direct or indirect signs of grazing (bridles, walls, terraced areas, shelters, ruins, etc.). These data are obtained from field analysis, supported by photointerpretation.
- Forestry uses. Presence of stumps with suckers, pollarded trees, etc.
- Invasive species. Degree of coverage of invasive species.
- Fragmentation. A population is considered isolated when it is surrounded by a completely deforested surface of at least 100 m in width.
- Hunting.
- Attendance based on distance from paths, tracks or roads.
- Archaeological elements. Reporting of the presence of archaeological elements.

Starting from the first analyses carried out, the most appropriate management aims for each case are defined. The forests that present a good state of maturity and naturalness can be left to evolve naturally, while for the populations that at the current state are characterized by a little heterogeneous structure and by problems of renewal and competition between the specimens, but that present the potential to become old-growth forests, it is recommended to carry out silvicultural interventions to improve their structural conditions.

The **interventions to be carried out** in the identified populations must be selective interventions that aim to promote the development of mature forests with natural dynamics, characterized by a greater degree of resilience to disturbances and climate change.

- In stands with low biodiversity, it will be important to generate a greater quantity of laying and standing deadwood, in order to favor the presence of saproxylic insects. This should be done through the technique of ring-cutting, applied to individuals with a diameter >20 cm.

- In young stands, competition for specimens with the best conformation is reduced by making selective cuts, to improve the general maturation process of the forest. In these cases, creating openings in the canopy layer to diversify the structure of the forest can also have a good effect. In addition, exotic species are eliminated. The trees selected for their elimination must be ring-cut. Near forest tracks or paths, the specimens to be eliminated must be cut at a height of 40-50 cm to allow the development of fungi, saproxylic insects and epiphytic flora and the trunks must be left on the ground.
- In larch pine forests that are highly vulnerable to large crown fires, prescribed fire techniques can be used to emulate the natural dynamics of a low-density fire and create a forest structure that is less vulnerable to crown fires. It is also a good idea to regulate public use of these forests, limiting recreational activities and allowing access to the forest only through guided tours.

The overall cost of the interventions to improve the structure of the Larch pine forests (selective cutting, ring-cutting of individuals, selective clearing of the undergrowth) amounts to €2,701/ha.

**Reference document**: Camprodon, J.; Guixé, D.; Sazatornil, V. 2018. Characterization and conservation guidelines for singular black pine forests. Life+ PINASSA. Publisher: Centre de la Propietat Forestal. 80 p.

## 4.3. Spain (Catalunia) - Silvicultural interventions aimed at improving the regeneration conditions of habitat 9530*

**Project**: LIFE+ Pinassa (LIFE13 NAT/ES/000724) – Sustainable management for the conservation of black pine forests in Catalonia

**In brief**: LIFE+ Project Pinassa has as its main objective to improve the conservation status of larch pine forests (habitat 9530* - (sub)Mediterranean endemic black pine forests) in Catalonia. To this end, the Project proposes actions aimed at the main problems and threats that this habitat faces, in 10 Sites of Community Interest (SCI). The conservation actions are based on the following specific aims:

- To improve larch pine stands stability, regeneration conditions, biodiversity status and decrease vulnerability to forest fires
- To increase the resistance and resilience of larch pine forests to forest fires and climate change
- Elaborate management plans to make forest conservation compatible with its productive and recreational use
- Disseminating information about the Natura 2000 network, the importance of the environmental value of these areas and their sustainable management.

**Website**: http://lifepinassa.eu/?lang=es

**Location:** Catalonia

**Territorial context**: of the area covered by the habitat 9530* in Catalonia, 23,058 ha (35%) are included in 28 Special Areas of Conservation of the Natura 2000 network. For the implementation of measures to improve the structure of mature larch pine forests, 3 areas were chosen between the Pre-Pyrenees and Southern Catalonia, included in 3 SACs for a total of 41.33 ha. In addition, a further 132.79 ha of mature larch pine forests were identified for natural evolution.

**Traditional type of management**: The slopes covered by larch pine forests in Catalonia were formerly used for grazing and timber production, activities that favoured the development of open woodland structures that allowed shady pastures to be maintained in a Mediterranean mountain climate, with green, desirable grass for longer. For this reason, the larch pine habitat has always been favoured on mid-mountain slopes in Catalonia and has never disappeared in the Els Ports, Tivissa-Vandellòs and Llaberia areas. However, with the socioeconomic changes that took place in the 20th century, these activities, and more generally the economic activities linked to the rural context, were abandoned, causing a progressive densification of the larch pine stands and a change in their structure with the growth of certain oak species in the dominated plane. These processes are considered to be one of the causes of the large forest fires that occurred in the 1990s in Catalonia, most of which affected larch pine forests.

**Forest habitat or forest type**: 9530*

**Aims**: through the management measures adopted, the aim is to improve the conditions of mature black pine forests that present regeneration difficulties and are characterized by a simplified structure and a low level of biodiversity. The specific aims of the practice are: 1) To promote natural regeneration through the opening of the canopy and the reduction of the density of the shrub layer; 2) To improve the heterogeneity of the forest structure, the ecological complexity and the biodiversity of the forests at landscape scale.

**Pressures/threats**: Regeneration problems in mature larcn pine forests are often due to a combination of factors such as excessive competition between undergrowth and seedlings, soil temperature and humidity conditions, and contact with the mineral component of the soil. These factors are correlated with canopy cover, shrub layer, and soil compaction.

**Case Study Description**: The interventions consist in the improvement of the forests' conditions for regeneration, reducing the density and creating opening in the crown cover depending on the light needs of each specific situation, extracting up to 40% of the basal area.

The main problems of each stand must be defined by creating permanent circular inventoried plots with a radius of 15 m, within which inventories related dendrometric data are carried out, and those related to site and stand conditions.

The inventories involve the collection of the following data:

- Number of plants/ha
- Diameter of all of the plants
- Height of all of the plants
- Number and species of small trees (< 7.4 cm of diameter)
- Coverage degree of the shrub layer
- Average height of the shrub layer
- Type of vulnerability to crown fires (low, moderate, high)
- Forest category
- Average of standing and fallen deadwood / ha
- Average of cavities/km
- Richness of flora of interest (N species / km)
- Abundance of flora of interest (N individuals / km)

Once this information has been obtained, the ORGEST management models can be consulted for the definition of the silvicultural actions to be carried out, related to the black pine forests (see attachments), and the management model that requires less structural change of the forest will be chosen.

Before carrying out the interventions, the individuals to be cut or girdled must be marked, one by one, with a spray by a specialised technician, using three colours for better defining the type of intervention: 1) trees to be cut, 2) trees to be girdled, 3) Trees to be cut at a height of 40-50 cm from the ground and to be left in the forest.

In general, the interventions foresee:

- **Preparatory cutting**: up to a maximum of 40% of the basal area is extracted by removing the dominated individuals with the purpose of beginning to restart soil's biological activity, thus favouring the regeneration process. In addition, other species are subjected to cutting, those that form a crown layer that could compromise the regeneration phase. During this phase, it is very important to leave the individuals with good characteristics for seed production, and favour the growth thereof. For this purpose, direct competition at the level of the crown is reduced.
- **Selective cleaning of the understory**: partial removal of the shrub layer, giving priority to the conservation of the shrub groups with less growth in height potential and of the less inflammable species. In particular, in the areas at high risk of fires, it is of vital importance to intervene on the shrub layer with a height of >1.3 m, reducing its coverage. It is recommended

to leave about 25-30% of the shrub coverage with a height of >1.3 m, conserving the protected woody species and of biogeographical interest and the fleshy fruit bearers.
- **Low pruning**: it is applied to deciduous species with a height of > 4 m, removing the branches with live leaves up to a height above the ground of 1.5-2 m.
- **Conservation of particular trees**: trees with microhabitats, forks in the upper portion, nests and standing dead trees.
- **Generation of deadwood**: trees which are susceptible to the formation of cavities and nests and that are protected by the crowns of the neighbouring trees are girdled in order to ensure their stability. Moreover, the individuals on which to apply this practice must have structural characteristics such to guarantee that they will keep standing as long as possible. However, individuals that have wood with good technological characteristics for wood production should not be chosen. In any case, the possible fall of these individuals must not affect forest trails, pathways or other elements of interest. Apart from standing deadwood, the quantity of fallen deadwood is increased by cutting individuals which are about 40-50 cm high and leaving the trunk on the ground. The felled trees will have to be homogeneously distributed throughout the stand, they will have to be left at no less than 20 m away from passable tracks and will not have to compromise the hauling of other material.

Average of the costs relative to the various interventions:
- Selective cleaning of the understory: 800 €/ha
- Preparatory cutting: 1990 €/ha
- Hauling: 800 €/ha

**Reference document**: Camprodon, J.; Guixé, D.; Sazatornil, V. 2018. Characterization and conservation guidelines for singular black pine forests. Life+ PINASSA. Publisher: Centre de la Propietat Forestal. 80 p.

## 4.4. Spain (Catalunia) - Restoration of habitat 9530* in areas affected by large forest fires

**Project**: LIFE+ Pinassa (LIFE13 NAT/ES/000724) – Sustainable management for the conservation of black pine forests in Catalonia

**In brief**: LIFE+ Project Pinassa has as its main objective to improve the conservation status of larch pine forests (habitat 9530* - (sub)Mediterranean endemic black pine forests) in Catalonia. To this end, the Project proposes actions aimed at the main problems and threats that this habitat faces, in 10 Sites of Community Interest (SCI). The conservation actions are based on the following specific aims:

- To improve larch pine stands stability, regeneration conditions, biodiversity status and decrease vulnerability to forest fires
- To increase the resistance and resilience of larch pine forests to forest fires and climate change
- Elaborate management plans to make forest conservation compatible with its productive and recreational use
- Disseminating information about the Natura 2000 network, the importance of the environmental value of these areas and their sustainable management.

**Website**: http://lifepinassa.eu/?lang=es

**Location:** Catalonia

**Territorial context**: of the area covered by the habitat 9530* in Catalonia, 23,058 ha (35%) are included in 28 Special Areas of Conservation of the Natura 2000 network. For the implementation of measures to improve the structure of mature larch pine forests, 3 areas were chosen between the Pre-Pyrenees and Southern Catalonia, included in 3 SACs for a total of 41.33 ha. In addition, a further 132.79 ha of mature larch pine forests were identified for natural evolution.

**Traditional type of management**: The slopes covered by larch pine forests in Catalonia were formerly used for grazing and timber production, activities that favoured the development of open woodland structures that allowed shady pastures to be maintained in a Mediterranean mountain climate, with green, desirable grass for longer. For this reason, the larch pine habitat has always been favoured on mid-mountain slopes in Catalonia and has never disappeared in the Els Ports, Tivissa-Vandellòs and Llaberia areas. However, with the socioeconomic changes that took place in the 20th century, these activities, and more generally the economic activities linked to the rural context, were abandoned, causing a progressive densification of the larch pine stands and a change in their structure with the growth of certain oak species in the dominated plane. These processes are considered to be one of the causes of the large forest fires that occurred in the 1990s in Catalonia, most of which affected larch pine forests.

**Forest habitat or forest type**: 9530*

**Aims**: restoring habitat 9530* in areas affected by large forest fires, promoting the regeneration of the black pine, where the persistence of the species is threatened, and the improvement of the habitat conditions.

**Pressures/threats**: In the larch pine forests affected by large forest fires, the natural regeneration of this species presents various problems, which generally lead to its replacement by other species, and therefore to the loss of habitat.

**Case Study Description**: In order to define the most appropriate interventions for each situation, it is recommended to analyse each stand to identify the limiting factors on which to intervene.

Note: These interventions do not have an immediate economic return for forest owners and must be considered as a necessary investment for environmental restoration. Therefore, to address habitat recovery actions, the involvement of administrations, large landowners and small landowners' associations is needed. In general, the main interventions include:

**Reduction of competition.** Proceeding with cleaning the undergrowth and cutting the other tree species present which are in competition with adult specimens or with the regeneration of larch pine or which create continuity between the undergrowth and the crown layer. Deciduous trees and shrub species producing fleshy fruits must be released and specimens of trees with cavities on the trunk must be kept, whether they are alive or dead, specimens with nests for birds of interest and specimens of large dimensions and tortuous habits that grow between rocks. It is also advisable to cut about 20 trees/ha to a higher than normal height, leaving a stump of about 40 cm to encourage the development of fungi and saproxylic beetles. The leftover material must be shredded on site, stacked or logged.
**Planting of seedlings (autumn).** This must be carried out in areas where the presence of adult larch pine individuals is scarce. 1-2 year old seedlings coming from the same biogeographical region are used, which must be planted at a distance of about 6 m from each other in groups, according to the orography of the land (avoiding rocky outcrops, areas with a high density of woody vegetation), to reach a density of 600 seedlings/ha. In areas characterized by long periods of drought, it is recommended to periodically irrigate the seedlings.

**Sowing (spring).** Sowing must be done under cover of groups of individuals of adult larch pine. Sowing must be done under cover of groups of individuals of adult larch pine. Sowing can be done through the following methods:

- sowing by hand (cheaper method but less likely to be successful)
- sowing 5 cm below the soil surface
- using seed bombs, made by adding 3-5 seeds in a manure compost and clay mixture and forming a ball of about 5 cm in diameter. The bombs must be spread directly on the ground in areas protected by the shrub layer or under cover of adult larch pine individuals. It is the most expensive method but most likely to be successful.

**Bat shelters.** One can proceed with the installation of bat houses in case one wants to protect or favour a threatened species or of interest, or for the biological fight against the pine processionary caterpillar. Cutting and clearing of the undergrowth must preferably be carried out outside the bird nesting period (April-May), and must not be carried out less than 200 m away from the nests of forest or rock birds of prey. It is important not to sow or plant seedlings near paths or areas frequented by tourists.

**Average costs per hectare:**

- Interventions to reduce competition and shredding of waste material: € 3540
- Sowing and planting of seedlings: €620

**Reference document**: Camprodon, J.; Guixé, D.; Sazatornil, V. 2018. Characterization and conservation guidelines for singular black pine forests. Life+ PINASSA. Publisher: Centre de la Propietat Forestal. 80 p.

## 4.5. Spain (Catalunia) - Use of silvicultural and prescribed burn techniques to reduce the vulnerability of larch pine woods to crown forest fires

**Project**: LIFE+ Pinassa (LIFE13 NAT/ES/000724) – Sustainable management for the conservation of black pine forests in Catalonia

**In brief**: LIFE+ Project Pinassa has as its main objective to improve the conservation status of larch pine forests (habitat 9530* - (sub)Mediterranean endemic black pine forests) in Catalonia. To this end, the Project proposes actions aimed at the main problems and threats that this habitat faces, in 10 Sites of Community Interest (SCI). The conservation actions are based on the following specific aims:

- To improve larch pine stands stability, regeneration conditions, biodiversity status and decrease vulnerability to forest fires
- To increase the resistance and resilience of larch pine forests to forest fires and climate change
- Elaborate management plans to make forest conservation compatible with its productive and recreational use
- Disseminating information about the Natura 2000 network, the importance of the environmental value of these areas and their sustainable management.

**Website**: http://lifepinassa.eu/?lang=es

**Location:** Catalonia

**Territorial context**: of the area covered by the habitat 9530* in Catalonia, 23,058 ha (35%) are included in 28 Special Areas of Conservation of the Natura 2000 network. For the implementation of measures to improve the structure of mature larch pine forests, 3 areas were chosen between the Pre-Pyrenees and Southern Catalonia, included in 3 SACs for a total of 41.33 ha. In addition, a further 132.79 ha of mature larch pine forests were identified for natural evolution.

**Traditional type of management**: The slopes covered by larch pine forests in Catalonia were formerly used for grazing and timber production, activities that favoured the development of open woodland structures that allowed shady pastures to be maintained in a Mediterranean mountain climate, with green, desirable grass for longer. For this reason, the larch pine habitat has always been favoured on mid-mountain slopes in Catalonia and has never disappeared in the Els Ports, Tivissa-Vandellòs and Llaberia areas. However, with the socioeconomic changes that took place in the 20th century, these activities, and more generally the economic activities linked to the rural context, were abandoned, causing a progressive densification of the larch pine stands and a change in their structure with the growth of certain oak species in the dominated plane. These processes are considered to be one of the causes of the large forest fires that occurred in the 1990s in Catalonia, most of which affected larch pine forests.

**Forest habitat or forest type**: 9530*

**Aims**: reducing the vulnerability of larch pine populations to crown fires. In the context of this general objective, the specific ones are the following: 1) reducing the fuel load in the shrub and herbaceous layer; 2) increasing the distance between the crowns of the tree layer and the shrub one to prevent that a surface fire could change into a crown fire; 3) decreasing the competition between the arboreal layer and the shrub layer, and between individuals, to favour the development of a more water stress-resistant forest structure and therefore less vulnerable to drought.

**Pressures/threats**: most of the larch pine forests are composed of monospecific stands characterized by a low stability structure, an insufficient regeneration capacity and a high risk of forest fires

**Case Study Description**:The practice is based on two planning levels:

1. identification of Strategic Management Points in which carrying out the interventions, areas where the operations of control and slowdown of the fires spread and extinction, can be easily carried out. The forest fire management manual by Piqué et al. (2011), available in Catalan language, collects a series of recommendations for the identification of the intervention sites and prevention of large forest fires
2. definition of the concrete actions aimed at reducing the fuel load in the intervention sites: the individuation of the interventions to be implemented, must be based on the ecological and structural of each stand characteristics which are inventoried through the creation of permanent circular sample plots with a radius of 10 m, within which the following data are collected:
    a. • Number of trees / ha
    b. • Diameter of all the trees
    c. • Height of all the trees
    d. • Live crown height
    e. • Crowns diameter
    f. • Average age
    g. • Number and species of small trees (<7.5 cm in diameter)
    h. • Degree of coverage of the shrub layer
    i. • Average height of the shrub layer
    j. • Vulnerability level to crown fires (low, moderate, high)
    k. • Forest category
    l. • deadwood standing and fallen average / ha
    m. • Cavity average / km
    n. • Flora of interest richness (N species / km)
    o. • Abundance of flora of interest (N individuals / km)

Once information has been collected, it may proceed choosing the most appropriate management model among the ORGEST management ones relating to black pine forests (see attachments). In the context of LIFE + Pinassa, the management models used to define the silvicultural interventions and those of prescribed burn, are Pn03, Pn08 and Pn10.

In general, the interventions include:

**Thinning from below**: eradication of trees dominated in a spatial homogeneous way, including the non-inventory specimens (diameter <7,5 cm), if they create a continuity between the shrub layer and the crowns of the arboreal layer, the sick and / or malformed tree specimens . The intervention must not let openings in the crowns layer, except when it is envisaged to perform a thinning from the bottom, when it is necessary to eliminate codominant specimens. In any case, a crown coverage> 75% must always be maintained, to prevent a rapid development of the shrub layer.

**Selective cleaning of the undergrowth**: partial elimination of the shrub layer, giving priority to the conservation of groups of shrubs with less growth potentiality in height, less flammable species and groups of shrubs that grow in the clearings and do not create continuity with the crowns of the tree layer. In particular, in areas with high risk of fire, it is very important to intervene on the shrub layer with an height > 1.3 m, reducing its coverage. It is recommended to release approximately 25% of the bush cover with a height > 1.3 m, preserving the protected wood species of bio geographical interest and those producing species of fleshy fruits.

**Low pruning**: it is applied to deciduous species of height> 4 m, eliminating the branches with live leaves up to a height above ground of 1.5-2 m.

**Deadwood creation**: it is carried out the girdling of trees with straight growth, with a diameter from 20 cm and an height higher than 4 m. In addition, trees with a diameter> 15 cm are cut at a height of 40 cm above the ground and leaving the trunk on the ground.

**Prescribed fire:** the undergrowth is eliminated (herb layer, shrub layer and small trees) by applying the prescribed fire technique, so to reduce the accumulation of forest fuel in defined areas. The intervention must be based on a prescribed fire intervention plan, previously approved, which specifies the conditions for carrying out the intervention in safety, for instance with respect to weather, fuel humidity and wind conditions, so as to guarantee the control of fire behaviour and effects, without causing damage to soil, vegetation and fauna. In addition, the intervention plan must specify the objective of the action, the activities previously carried out for the preparation of prescribed fire, the necessary resources and ignition techniques. The preparatory works consist in the creation of delimitation strips useful to reduce the area subject to fire. The vegetable residues produced during the preparatory work, must be evenly distributed in the parcel, in order to avoid too high-intensity fire due to the accumulation of dead branches. Once the ignition phase is completed, the extinction operations are carried out through cooling the hot spots and the delimitation land strips. In high drought conditions, to avoid the spread of fire, it is necessary to wet an additional strip of 20 m from the perimeter strip.
**Monitoring**: in order to reduce possible negative impacts due to the prescribed fire, once the operations are completed, the soil temperature (it must not be too high) and the regeneration process must be monitored.

**Reference document**: Camprodon, J.; Guixé, D.; Sazatornil, V. 2018. Characterization and conservation guidelines for singular black pine forests. Life+ PINASSA. Publisher: Centre de la Propietat Forestal. 80 p.

## 4.6. Italy (Tuscany) - Selective thinning in artificial populations of *Pinus nigra*

**Project**: SelPiBioLife (LIFE13 BIO/IT/000282) - Innovative silviculture to improve the biodiversity of soils in artificial stands of black pine

**In brief**: the project aims to show the positive effects of a specific silvicultural treatment on forests of *Pinus Nigra* of artificial origin. Such effects concern not only the growth of plants and the stability of the topsoils, but also, in particular, biodiversity at the understorey level and at the soil level (fungi, bacteria, flora, mesofauna, nematodes). In particular, the effect of an innovative thinning of the selective type is shown, compared to the traditional modality (thinning from the bottom) and compared to the absence of treatment on pine populations in the juvenile phase. It is shown how this management technique not only stimulates plant growth and the stability of forest populations, modifying the type of canopy of the crowns, but also determines a different light, water and temperature regime at the soil level, favouring the growth of biodiversity and the overall functionality of the ecosystem with a resulting increase in the economic, touristic and hydrogeological protection value.

**Website**: https://www.selpibio.eu/

**Location:** Tuscany Region

**Territorial context**: in Tuscany, forests which are predominantly composed of black pine and larch pine extend for a total surface of about 20.500 hectares. In the pilot area of Pratomagno the pine forest had an average age of 59 years (in 2015). This is an even-aged and single-storied pine forest with the absolute predominance of larch pine, associated locally with silver fir groups (especially at higher altitudes of the area) and a marginal contribution of sporadic broadleaved species. All the other species account for 13.8% of the basal area in total. The density of the pine forest is too high for the stand age with respect to the yield model, which predicts about 800 plants per hectare. The larch pine plants of average characteristics have a slenderness ratio of 65, as evidence of a good degree of average stability of stand. In the pilot area of Monte Amiata the pine forest had an average age of 44 years (in 2015). This pine forest is one-storied, second class of fertility with respect to the black pine yield model in Tuscany. The specific composition is of larch pine absolute predominance, associated locally with other species (especially Turkey oak) originating mainly from previous land use residue patches (degraded coppice and pasture with isolated oak trees). In terms of percentage of basal area other species contribute to specific composition for less than 3% of the total. The species diversity of sporadic tree species is much more mixed in terms of number of species compared to Pratomagno stand. The average density of the pine forest is less than that of Pratomagno even if the pine forest is younger. Probably some pine forest sections, in the past, have been exposed to a light thinning from below. Laricio pine trees of average characteristics have a slenderness ratio of 75, value greater than that seen in the Pratomagno, although in the stability range for the species.

**Traditional type of management**: the forests of Pratomagno originates from a reforestation intervention that started in 1954. The main aim was to rapidly rebuild the forest canopy on extended steep areas without vegetation for hydrogeological protection. About a decade after planting all reforested areas were cleaned up. Since 1980, the complex has been the object of 3 management plans in which the current one is in force until 2021. The first two plans only provided cultivation provisions (clearing out and thinnings), with the last plan the overall treatment of the pine forests starts to be considered. In practice the strategy management refers to a gradual progression of the pine forest towards a transformation into a mixed forest with a stratified structure through punctual interventions ('oriented' silvicultural method). In practice the concept of shift is abandoned and a long-term forest persistence is envisaged.

Until 1936, the area of Monte Amiata was mainly characterised by pastures and arable land, and areas occupied by mixed coppice oak-dominated. Until 1954, the forest area gradually increased, very likely due to abandonment of farming activities. Presently, the effect of reforestation results in an almost total coverage.

**Forest habitat or forest type**: artificial pine forests

**Aims**: demonstrate how an innovative silvicultural treatment method applied to artificial pine forests can improve the forest multifunctionality, optimizing the characteristics of the stand with regard to the overall mechanical stability (protective function), growth capability of the plants (productive function), structural differentiation (biodiversity increase function). Particular attention is given to the hydrogeological protection function and the biodiversity increase in the soil environment (fungi, bacteria, flora, mesofauna, nematodes).

**Pressures/threats**: Apennines pine forests are generally monospecific and monoplane.

**Case Study Description**: It's a regime of free thinnings with a positive selection. The thinnings are defined "free" when they do not provide a specific class of plants to be harvested and focus rather on the specific characteristics and phenology of those to be left. This kind of thinning aims at enhancing an average number of trees with good potential development. Due to the primarily protective function of the black pine Apennines forests, the trees "selection" will be made on those trees that provide the greatest degree of mechanical stability, even if, generally, the pines with a good degree of stability are also those of great productive potential. This kind of treatment, for ease of discussion, will be henceforth called "selective thinning". Always for ease of discussion, the term "elite" will be adopted for the selected vigorous trees to be enhanced with treatments. The selective thinning adopted by the SelPiBio project acts with a first treatment in a young high forest (age 30-40 years) not thinned or at least submitted to low-intensity thinning from below. The reference structure is currently most represented by artificial black pine stands in the Apennines.

The proposed method is based on experimental valuations and has the characteristic of being easily reproducible and easy to implement. The method is valid for stands of an average-good plant vigour of regular density and with no pathologies ongoing.

Tree marking of the first selective thinning is characterized by

1. positive selection of the elite trees to constitute the stand at the end of the rotation period;
2. identification of "direct competitors" intended as all of those that represent an obstacle for the free growth of the elite crown.

The selection of plants to be enhanced in coniferous forests is hardly feasible in the early development stages because of insufficient social and phenotypic differentiation of arboreal plants, which is more evident during the young high-forest stage. The recent trend of larch pine forest silviculture in Spain has recognized this need, suggesting (in a customary thinning system) the first two intermediate cutting in the juvenile stage as mechanical or from below thinning, then, around 30 years old, operate a thinning with selection of final crop trees. With the first selective treatment in the development stages of pole/young high forest, the elite trees selection was carried out, whether or not the stand has the planting density or previous interventions from below have been realized. The average number of elite trees should be around 100 trees per hectare. The density of 100 trees per hectare (10 meters, average distance between trees) comes from the analysis of crown development patterns of black pine in the absence of lateral competition and by experimental data taken ad hoc. This number represents the optimum average density of the pine forest at 100 years old. In order to make the treatment simple and easily reproducible, we suggest spatially locating elite trees according to a regular design. It is recommended to mark them with a team of two operators. Starting from the lower elevation of the treated area and proceeding for contour lines on higher and higher elevation, once the first candidate has been chosen and marked with a strip of paint, an operator stays next to it, while the second one moves to the second candidate. This makes it possible to evaluate briefly the distance between the two elite trees (around 10 m). Repeating the operation to the contour lines above, the paint stripes placed on the elite trees will support for proper regular space between the elite trees disposal. The regularity of spatial location is obviously not a strict rule. The 100 trees per hectare are an indicative number, as well as the distance of 10 meters between an elite tree and the other must be considered an average distance. The operator must consider from time to time to change the rule for the absence of elite trees from the theoretical distance, or for local site emergencies (rocky soil, landslides, etc.)

For a correct choice of elite trees the following must be evaluated:

1. the specific composition;
2. the vigour;
3. the degree of mechanical stability;
4. the mechanical and/or pathological damage;
5. the stability groups.

Within the choice of elite trees we have an opportunity to address the stand from a specific composition point of view. It is a management choice, closely dependent on the stand characteristics. The black pine forests of the Apennines, in fact, have often some degree of species mixture, due to localized planting of different species from pine at reforestation time (frequently sycamore and silver fir at higher elevations or Turkey oak, holm oak, cypress or other conifers at lower elevations) or for the pre-existence of the degraded forest before planting (often chestnut or oak trees). The choice to select other species than the pine must be cautious and be limited to those trees that can guarantee with their vigour a good reaction to the treatment. When there are sporadic tree species with high commercial (especially valuable sporadic species) or ecological (any habitat trees) value, it will be a good practice to choose them as elite trees. The elite trees must belong to the stand dominant layer (and therefore must have diameters and heights above average stand parameters). The dominant trees that have vegetated for a long time above the crowns of close trees will be preferred. It is important that elite trees have a crown as dense as possible. Due to the predominantly protective function of black pine forests in the Apennines, the evaluation of this parameter is the most important. In selective thinning of black pine forests a very important phase is that of choosing the elite trees. The choice must be based on the phenotype as a function of mechanical stability and vigour. The choice to use this thinning type is closely dependent on the presence in the stand of a sufficient number of stable trees to candidate. Forests with a lack of mechanically stable plants will have to be treated with other types of thinning.

The elite tree should have:

1. a low slenderness coefficient (less than 90);
2. a high crown depth;
3. the crown as symmetrical as possible;
4. the crown as ample as possible.

The elite trees must be free from mechanical damage (break off or forked crown, lightning damage to the trunk, ungulate damage, etc.) and pathological damage (evidence of fungal bodies or insect attacks). It's possible to select small groups, two or more trees, when it is considered that they represent a group of mutual stability, consisting in dominant trees with crowns overlapping. Such groups of elite trees will be treated as a single elite tree and then, as such, will follow the thinning rules.

After selecting the elite trees, the next step is to rid their crown from near competitors. The competitor trees are those that hinder the natural development of elite trees' crowns directly. It would then be enough to free the elite trees from dominant and co-dominant trees (located in the overstorey) that are in direct competition with them. To ensure a greater effectiveness of this procedure with increasing stand structural differentiation and contribute to increase micro-climatic changes on the ground (light and water) and encourage biodiversity at ground level, it is recommended to harvest even the dominated trees near the elite tree. The harvest of competitor trees is intended to release all elite trees' crowns, creating discontinuity between the whole maximum crown width of each elite tree and the crown of its potential future competitor trees.

The forest stand fraction not directly affected to selective thinning can be treated alternately with two modalities:

1. to leave untouched all of this stand fraction;
2. to achieve moderate thinning from below.

Both modalities preserve the thinning efficacy from a technical point of view. It is, in fact, a harvest of a portion of dominated trees, which will not influence competitive relationships of the dominant layer. However, the choice of leaving untouched all of the stand fraction helps to differentiate more the structure (coexistence of dense stand areas and micro gap in canopy cover). Later thinning will be repeated when the elite trees' crown will come in contact with their direct competitors. The time between a treatment and the next one (treatments frequency) depends on several factors:

1. the first selective thinning intensity. The time between a treatment and the next one is directly related to the intensity of the first treatment (and therefore the distance between the crowns created after thinning);
2. the stand development stage. The most reactive capability of trees growth in juvenile stages suggests an higher frequency among treatments if the first selective thinning was performed during pole stage/young high forest;
3. the site fertility (inverse correlation between the degree of fertility and treatments frequency).

Thinning after the first treatment conceptually follows those already seen for the first treatment. Key point is always to act in order to rid the elite trees' crown of nearby competitors for light with the first thinning. Operatively, elite trees will be recognized from their ring around the trunk, made with indelible paint at the stage of first selective marking. In the case of tree mortality, or damage, among the elite trees they can be (if necessary) replaced with another adjacent vigour tree.

**Reference document**: Cantiani P. (ed), 2016. Selective thinnings. Increasing mechanical stability and biodiversity in black pine plantations. SelPiBioLife technical handbook (Language: English, Italian).

# 5. General approaches and techniques

## 5.1. Italy (Tuscany) - Silviculture of sporadic species in mixed forests

**Project**: LIFE PProSpoT (LIFE09 ENV/IT/000087) - Policy and protection of sporadic tree species in Tuscany forests

**In brief**: the Project aims at introducing in Italy, and in particular in Tuscany, the tree-oriented silvicultural technique applied to the management and conservation of sporadic tree species in forests. This silvicultural approach consists of carrying out thinnings from the top around a limited number of selected plants, known as target plants, in which certain light conditions take place, which favour the development of their crown, their fructification and their wood production. This approach is suitable for sporadic species in that it allows to carry out thinning interventions which are different according to the needs of the various species. The valorization - that is, also economical - of these rare and often endangered species is proposed for increasing the biodiversity, ecological equilibrium and value of forests by implementing an innovative technique, which can be integrated with traditional techniques, and which can easily be spread. The project has realized 95 ha of interventions, two pilot management plans, three marteloscopes where many training courses for workers and specialists of the sector have taken place; Changing the Tuscany Forest Law which have provided the possibility of carrying out tree-silvicultural interventions and group of standards in coppices.

**Website**: https://www.pprospot.it/

**Location:** Tuscany region

**Territorial context**: The project has developed within the "Colline Metallifere" (Metalliferous Hills) (GR), a hilly area near the Tyrrenian sea, and that reaches heights of 800-900m a.s.l., and the "Appennino Pistoiese" (Pistoiese Apennine) (the Abetone and Melo forests), characterised by mountain areas that can reach 2000m a.s.l.

**Traditional type of management**: in the area of "Colline Metallifere" are public forests within the agricultural and forestry heritage in the Tuscany region, managed by the Union of Mountain municipalities of the "Colline Metallifere" characterized by the prevalence of coppice forests of turkey oak or of mixed broad-leaved trees and secondarily of chestnut coppices currently managed as coppice with stands and in part converted to high forest. Coppice logging is generally done by selling the standing forest to private companies, while start-up interventions are generally done according to direct administration. Also in the area "Appennino pistoiese" are regional planned forests (Abetone and Melo Forest) managed by the Union of the Municipalities of the "Appennino Pistoiese". In this case these forests are dominated by beech and fir trees and secondly by coppices of chestnut and Turkey oak. Forest interventions are both contracted to private companies and carried out by direct administration. The interventions comply with the indications of the management plans, as they are region-owned forests.

**Forest habitat or forest type**: chestnut, beech and turkey oak forests

**Aims**: conservation and development of sporadic species achieved through the application of tree-oriented silviculture techniques. It aims therefore to increase the conservation of arboreal biodiversity, enhance the production of valuable wood that can be obtained by many existing sporadic species, obtaining not only firewood but also valuable logs that can be used after 2-4 coppice rotations, thereby improving its value.

**Pressures/threats**: Italian coppice woods in the Mediterranean and Apennine areas feature a progressive simplification of the specific composition of forest formations, especially to the detriment of some broadleaves, commonly called "sporadic forest species", due to their poor presence. This simplification can be attributed to various factors including: 1) lower competitiveness compared to species numerically dominant. The application of interventions such as coppicing has determined a progressive reduction of the sporadic species enhancing dominant species, better adapted to this type of silvicultural management. Many sporadic species are found mainly in the dominant layer, with a consequent difficulty of the gamic reproduction, and this causes a progressive reduction of the more light demanding species; 2) cultivation techniques that aim to maximize biomass production for energy purposes without taking into account potential alternatives (timber for furniture, handicrafts, etc.) dictated by the peculiar characteristics of each area; 3) progressive aging of forests dominated by coppice that, moving towards structures similar to those of high forests, tend to form monospecific and monolayer topsoil to the detriment of the less competitive species; 4) poor knowledge from owners and forestry businesses of alternative techniques to traditional ones; 5) difficulty to obtain authorizations for non-traditional forest management interventions for lack of technical indicators that allow simple verifications of the correct execution of innovative silviculture practices.

**Case Study Description**: tree-oriented silviculture consists of localized thinning around sporadic plants in order to favour their conservation and their economic valorisation. Their application must be made by integrating it with the management of the remaining part of the topsoil. In the case of coppices, it is advisable to limit this type of silvicultural approach to fertile areas, well connected by roads and characterized by a sufficient number of sporadic species, so as to make the integration between the two silvicultural approaches easier. Once the areas where we want to work are identified, it is then necessary to select and mark the best specimen of sporadic species (target plants) considering the following aspects: vigour of the plant, quality of the stem, crown size, spatial distribution and rarity of sporadic species. The target plants must be chosen at a minimum distance among the selected trees nearby (8-14 m), variable in function of the potential growth of the species so as to allow adequate development of the foliage until maturity. Silvicultural practices around target plants are different according to the evolutionary state of the topsoil and of their context. We can therefore observe the following situations:

<u>Situation type T1</u>: localized thinning is performed from the top around the target plants of sporadic species before logging the coppice. Generally, a first intervention at midway of the coppice rotation might be advisable. The foliage of the target plants is freed by cutting the main plant competitors or, in the case of unstable trees, reducing the growth of competitors by the use of “cassage” and girdling techniques.
<u>Situation type T2</u>: it takes place when it is necessary to use the topsoil with coppicing and the target plants of sporadic species to be released are not sufficiently developed. In this case it is necessary to leave a ring of shots around the target plants as a protection and shade of the stem of the target plant, reducing the danger of epicormic branches and of damages due to the abrupt isolation of the plants.
<u>Situation type T3</u>: it occurs when, during coppice logging, it is possible to locate stable target plants with sufficiently developed canopies capable of directly shading the stems that have reached the phase of targeted sizes. In this case, if it has been decided to let them grow, it is possible to release them at the time of the cut plant by plant.
The application of these techniques is more effective if they are made on young stands and populations characterized by heliophiles. In beech woods (coppices or high forests) the conservation of sporadic species is certainly harder given the strong tendency of the beech to form pure topsoil. In this case the conservation of sporadic light-demanding species (service trees, cherry trees, laburnum, etc.) is more difficult, and they can be preserved by acting early on and only in open areas such as clearings and along roads. It is easier to preserve sporadic species with features like beech (such as lime, sycamore, yew, etc.) that tolerate better beech competition. In the high forests tree-oriented silviculture can be applied not only for the conservation of sporadic species, but can be applied inside the top layer by selecting from 50-100 target plants per hectare around which early and frequent thinning from the top shall be

carried out. Experiences in this regard have been made in the PProSpoT project on beech forests (30 and 50 years) originating from subsequent cuts previously never affected by thinning.

**Intervention costs** vary depending on the evolutionary state of the topsoil from a few euros per plant to a few hundred euros if hauling is included. Consultations of the manuals stemming from the project can be useful as well

**Reference document**: Mori P., Pelleri F. (eds), 2014. Silviculture for sporadic tree species. Extended summary of the technical manual for tree-oriented silvicolture proposed by the LIFE+ project and PProSpoT. 34 p (Language: English, Italian).

Andrighetto N., Bruschini S., Ciucchi B., Fratini R., Marone E., Pettenella D., 2014. The economy of sporadic tree species. Financial evaluation of the tree-oriented silviculture: the results of the PproSpoT Project. 68 p. (Language: English, Italian)

## 5.2. Spain (Catalunia) - Practical recommendations for the implementation of innovative silvicultural interventions

**Project**: LIFE MIXFORCHANGE (LIFE15 CCA/ES/000060) - Innovative management strategies for adapting mixed sub-humid Mediterranean forests to climate change

**In brief**: The main objective of the project is to contribute to the adaptation and greater resilience of mixed sub-humid Mediterranean forests to climate change, favouring their conservation and the maintenance of their productive, environmental and social functions. Specifically, the project aims to: i) develop and implement innovative forest management techniques, which allow forests to adapt to climate change and improve ecological and economic value in the medium term; ii) develop new tools to integrate the adaptation of sub-humid Mediterranean forests to climate change into the policy and laws on forest management; iii) develop new tools to strengthen the economy linked to the products provided by these forests, preventing or reversing their abandonment; iv) transfer the tools and techniques developed and results obtained taking into account the main stakeholders (forest owners, technical staff and public administration) at a regional, national and European level, and raise social awareness on the challenge of adapting forests to climate change.

**Website**: www.mixforchange.eu

**Location:** Catalonia

**Territorial context**: the project activities have been implemented in 197 ha of mixed forest in the Catalan sub-humid Mediterranean, in four geographical areas in northeast Spain. The four areas where pilot demonstration stands were located are:

- Montnegre-Corredor: Littoral low mountain conditions (maximum altitude 760 m, distance to sea < 10 km), warm temperatures and high precipitation (Foëhn), steep slopes, densely populated. Silica substrates.
- Montseny: Pre-littoral high mountain conditions (maximum altitude 1700 m, distance to sea 20-40 km), low winter temperatures and high precipitation (Foëhn), steep slopes. Silica substrates.
- Bellmunt-Collsacabra: Continental Mediterranean mountain conditions (maximum altitude 1300 m, distance to the sea> 50 km), low winter temperatures and medium precipitation, high slopes. Silica and calcareous substrates.
- Ripollès: Conditions of continental Mediterranean mountain, in transition to eurosiberian from Pyrenees (altitude maximum 1500 m, distance to the sea> 50 km), low temperatures in winter and average precipitation, high slopes. Silica and calcareous substrates.

**Traditional type of management**: conventional forest management or no silvicultural intervention in recent decades, after long periods of somewhat intense use

**Forest habitat or forest type**: generally applicable

**Aims**: adaptive silviculture aims to promote forest resistance and resilience to the current and projected impacts of climate change. The aim is to maintain the woods' vitality, fostering their adaptive capacity, maintaining their role as carbon sinks – mitigating the effects of climate change– and providers of essential goods and services, by means of forest management.

**Pressures/threats**: sub-humid Mediterranean forests of great environmental, productive and social interest are subject to threats that jeopardize the provision of many of these ecosystem services. Although the stands are, in general, mixed and show a certain degree of stratification, the prevailing form of management has progressively led them to a certain point of structural and species simplification. Many of these forests are found in a state of abandonment, with no silvicultural intervention in recent decades, after long periods of somewhat intense use. Furthermore, few management models for this type of formation exist. Moreover, the few existing guidelines on silviculture are, in general, little specific and markedly qualitative.

**Case Study Description**: the demonstrative silvicultural interventions of the MixForChange project have represented a rich practical learning experience on all levels of decision-making, from the design of the treatments to their implementation and follow-up. The silviculture method applied is based on reducing competition and promoting the most vital trees, augmenting forest complexity (on both a species and structural level), conserving biodiversity and promoting the forests' productive value, and diversifying products. In addition, the application of this form of silviculture incorporates close-to-nature and single-tree management principles, supporting multi-layered structures, a high level of detail in the interventions and an increase in the presence of sporadic broadleaf trees, including cherry, ash, maple, sorb, etc., and other potentially useful species for valuable timber production or from the point of view of biodiversity (rare species, trees with relevant microhabitats, etc.). From this experience, recommendations for replicating this innovative silvicultural approach can be extracted, considering its different phases and differences with respect to more conventional practices, as described below.

**Phase of diagnosis:** it is essential to possess a thorough knowledge of the current conditions of the habitat, the stand and the trees composing it, as well as of the natural dynamics, both current and past. In this way, it will be possible to determine the potential and establish the management options for the goals proposed.

To adequately capture the heterogeneity of mixed stands, the forest inventories have to be adapted, it being possible to assess the combination of plot-based inventories with an expert estimation traversing the stand. In addition to quantitative indicators, qualitative indicators should also be employed to describe the variability and potentiality observed (for example, incorporating a section of literal silvicultural description in the stand diagnosis).

**Definition of the planning on a strategic scale:** based on the diagnosis of each stand, the general management framework is defined on the forest (property) level. The first decision is to assign overall goals for each intervention unit. The goals in each stand must consider its context and the stands surrounding it or associated by location or by infrastructures of access and defence, seeking maximum economic efficiency. This type of silviculture does not need to be implemented in every stand, but rather various management approaches may be combined as long as the general goals on the forest level are kept in mind.

The prioritization of the stands in which to implement this silvicultural approach is a key decision, especially in a first application, as it entails a change in management. The best results of the MixForChange silvicultural approach are obtained in stands with high productivity and a certain level of capitalisation and social stratification, but with intermediate ages (phase of development). In these conditions the stand still has the capacity to react and time to evolve toward an adequate structure for unveiling the full potential of this form of management. Thus, it is advisable to prioritize the first application of this silviculture system in these more favourable stands, allowing the practice and results obtained to encourage and facilitate progressive replication in other stands: young homogeneous stands in the pole stage (with a lot of time ahead to adapt the structure but little current capital) and, in the last place, in more or less heterogeneous but aged stands, in which it may prove too late to achieve all the goals of this form of silviculture.

The definition of the management system to implement in each stand, whether by adopting reference management models or describing the silvicultural characteristics for the present formations, must incorporate an important component of flexibility to include all the precepts of this type of silviculture. The executive decision is made on the scale of a tree or group of trees, considering many factors observed on a small scale, which is why the rules of management must be limited to contributing the context criteria.

**Design of silvicultural interventions:** defined in the field and never on paper alone. Thus, prior to the design, a meticulous visit of the stands must be conducted to visualize the conclusions of the diagnosis and acquire a precise idea of the dynamics in place. The goals are proposed on a long time scale, which is why not all the changes ought to be pursued in a single intervention. In any event, the intensity proposed must make it possible to accomplish real changes in the conditions and maintain the productive capacity of the forest.

In most of the project's stands, it was deemed necessary to reactivate natural regeneration, especially of sporadic species. Thus, the design must take the favourable micro-sites into account, paying special attention to the entrance of light and the available space.

One key aspect is to communicate, in a practical way, the criteria for selecting future crop trees: for their commercial interest or for biodiversity. In the first case, vigorous and well-formed trees are selected to produce valuable timber, attending to their current and potential state. In the case of future crop trees selected for biodiversity, trees from underrepresented species or with valuable microhabitats are prioritized. Similarly, it is also essential to ensure the adequate transfer of the identification criteria of the future crop trees' main competitors , that is, the individuals which most intensely impede the expansion of the future crop tree's crown. Thus, the main competitors are identified observing the crown layer and also taking into account the species' temperament, relative orientation and position on the slope. In general, the most competition is exercised by the trees most tolerant of shade, situated to the south and in higher positions. As for the future crop trees selected for their commercial value, it is essential to maintain the trees placed around them which cast shade on their trunks but do not compete at the crown level, as their elimination could induce the emission of epicormic shoots on the future crop tree.

**Execution of the silviculture: marking.** Marking is an essential intervention for transferring the goals from the planning and design to the real execution. This marking must be performed by qualified professionals in the application of this form of silviculture, and the operations of tree felling and logging (haul and extraction roads, piling sites...) must be considered during its execution. Apart from accomplishing a detailed application of the foreseen silviculture system, marking makes it possible to augment the productivity and safety of the crews who execute the forest works. The general recommendation is to perform a complete stand marking, preferably before conducting any other intervention. Nonetheless, if interior visibility and walkability is seriously impeded by undergrowth, it may prove useful to perform a clearing operation before marking, accepting that a certain amount of direct information on the growth conditions of each tree, especially juvenile trees, will have been lost. If the stand and the intervention are somewhat homogeneous and the crews are experienced, partial markings in training areas may be considered. The marking code (colors, shapes, position of the marks) must be clear and agreed upon by all the personnel involved. It is advisable to mark the trees to cut with forestry paint, in a single, highly visible color, in the most visible position for the staff who executes the marking and for the staff who will perform the felling (for example, a red dot on the trunk on the upstream and downstream faces, plus a dot under the height at which it will be cut, which acts as a control). The future crop trees should also be marked with another color and shape (for example, a horizontal white line on the upstream and downstream faces) to facilitate a full view during the process of marking and to indicate to the felling staff that these trees must not be harmed. The marking of other trees which must necessarily be respected, whether for motives of biodiversity or to exert a favourable effect on the shaping of a future crop tree (e.g. nearby trees shading the trunk, without competing for light), also facilitates execution and prevents misunderstandings. In any event, it is fundamental to ensure that the workers executing the works comprehend the management criteria applied, whose transmission must be done gradually and with periodic follow-up throughout the execution. It is advisable to work with qualified, highly professionalized crews with sufficient experience and who gree, motu proprio, to follow the rules of work, risk prevention, health and safety and the optimisation of methods and equipment, because it represents a determining factor for the intervention's efficiency and results (Garcia, 2022).

**Silviculture implementation: interventions in the tree and understorey layers.** For the execution of the interventions, it is advisable to define and apply a series of good practices which have a favourable effect on maintaining the forest's functions. It consists in explaining how to implement certain actions or what not to do during felling, lopping, hauling and piling to improve the work's efficiency and safety and prevent or minimize negative impacts on the environment.

Examples of good practices in  arboreal-layer operations: in trees to fell which are in contact with a large rock or show a very pronounced basal curvature, a tall stump is left to facilitate felling and processing (in addition to generating dead wood); not cutting ivy unless they are very abundant and affect future crop trees; performing the felling and hauling without damaging future or juvenile trees and without altering mosses on trunks or rocks, areas of water accumulation or drainage, rocky spaces or terraces; not lopping over incipient regeneration or small patches with herbs (especially if there are flowering species); not hauling trees of little value if they are difficult to access; not slicing dead trees in the soil.

Examples of good practices in interventions on understory: perform clean cuts at the base without leaving sharp points which would suppose a risk; not affecting juvenile individuals of arboreal species if it is not explicitly indicated in the design; not chopping up material which is non-woody or under 5 cm in diameter; preventing debris accumulations higher than the knee.

**Product classification**: this form of silviculture gives rise to a wide range of wood products, which reinforces the previously mentioned need to employ qualified crews who optimize the logistics of extraction and classification, reducing idle time, avoiding excessive handling or facilitating the processes of loading and unloading. In the first interventions in little capitalized stands, the highest-value products will appear in very limited quantities, which is why possible options for concentrating the offer must be explored.

**Follow up**: The assessment of results, even in the short term, makes it  possible to improve the capabilities and experience of the personnel involved, both to improve the design of future interventions in the stand as well as to intervene in new stands. It is advisable to monitor on a regular basis, in addition to the diagnoses made during the revision of the planning instruments. In these assessments, special attention should be paid to the impact of extreme climatic phenomena on the intervened stands.

The total costs fall between 1,850 and 4,200 €/ha.

**Reference document**: Coello J, Piqué M, Beltrán M, Coll L, Palero N, Guitart L. 2022. Adaptive and close-to-nature management in mixed sub-humid Mediterranean forests: holm oak, chestnut, common oak and pine woods. Forest Science and Technology Centre of Catalonia, Solsona (Lleida, Spain); Forest Ownership Centre, Santa Perpètua de Mogoda (Barcelona, Spain). 104 p. (Language: English)