Interventions planned in the Biodiversity Islands

The case study of the project site “Montes Forest”

W3 – Tools for CNF management

Table of contents

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1. The LIFE project GoProForMed

In the Mediterranean region, forest habitats face threats not only from climate change and extreme events but also from management practices aimed at wood harvesting, which hinder the achievement of satisfactory conservation status. Additionally, there is a lack of a common system for recognizing and classifying forest habitats and for clearly assessing their conservation status. Knowledge gaps include defining features and indicators of forest habitat types' conservation status, identifying favorable indicator values, and determining typical species for each habitat type. There is also a need for better information to identify forest habitat types in the field. Overall, there is a lack of clear and shared transnational strategies for the conservation of Mediterranean forest habitats.

The main goal of LIFE GoProForMED is to improve and/or not worsen the conservation status of four target forest habitats in the Mediterranean Biogeographical Region. This will be achieved through the application of flexible, close-to-nature management models in 12 sites, falling within Natura 2000 sites in four representative countries: Italy, Spain, France, and Greece.

The project's target forest habitats are: 9330 - *Quercus suber* forests, 9340 - *Quercus ilex* and *Quercus rotundifolia* forests, 9260 - *Castanea sativa* woods, 9530* - (Sub-) Mediterranean pine forests with endemic black pines.

These habitats are not only representative in terms of surface area but also sensitive to management practices that can accentuate regressive effects, threatening their conservation status.

All target habitats involve silvicultural activities, making it essential to provide innovative and economically sustainable planning and management tools. These tools should enable the pursuit of production objectives without hindering biodiversity improvement and structural heterogeneity of the forest.

Specific project objectives include:

- establishing a transnational conservation strategy for forest habitats in the Mediterranean biogeographical region, with a focus on priority habitat 9530*, considering the main risk of deterioration due to forest fires;
- defining and applying conservation practices for the four target habitats, especially priority habitat 9530*, in demonstrative form;
- promoting the adoption of suitable forest management to improve the conservation status of the target habitats, shared among the main actors of forest management in the Mediterranean biogeographical area through training activities and management tools;
- disseminating knowledge on the N2000 Network and close-to-nature forest management to the target audience of the sector.

2. The ecological network within LIFE GoProForMed

A typical natural forest ecosystem can be described using a number of key ecological qualities (Dudley, 2011; Vallauri, 2007; Vallauri et al., 2010). These include:

- Diversity of trees, species and habitats,
- Nativeness,
- Forest stand structure (including different-sized forest gaps, diverse tree ages or diameters and vertical structure),
- Microhabitats of the living trees,
- Maturity of living trees and diversity of age classes,
- Presence of deadwood,
- Forest dynamics,
- Continuity in time of forest cover,
- Continuity in space, connectivity and large scales..

The set and complexity of these key characteristics, although none exclusive, mandatory or binary (Mansourian et al., 2013), re key determinants of the vulnerability, resilience and adaptive capacity of forests. It is important to point out that in different forest types, different characteristics may dominate, and also, for each characteristic, more specific thresholds can be set for different forest types and climatic conditions (see e.g: Peterken, 1996).

However, in general, forests composed of more tree species are often richer in biodiversity, more resilient and more functionally diverse (Forest Europe, 2020; Van der Plas et al., 2016). The presence and diversification of structural elements such as dead wood, microhabitats, senescent trees, forest gaps of different sizes, etc.) contribute to increasing and enhancing forest biodiversity, and in turn, biodiversity positively influences ecosystem functions and services, including CO_2 absorption in terrestrial ecosystems (Naeem, 1994). Continuity in time of forest cover has strong implications on soil processes and the occurrence of species with low dispersion rates. Large scales enable movement of species and genes, provide more flexibility for adaptation and recovery from threats (resilience). Large scale conservation and maintaining or restoring connectivity in landscapes is fundamental for the survival of many endangered species (Mansourian et al., 2013).

Maintaining or restoring the different components of forest biodiversity requires a comprehensive concept that combines segregative (reserve) and integrative (off-reserve) conservation tools to sustain species within the hotspots of their presence and throughout the matrix, at different spatial and hierarchical scales (Bollmann & Braunisch, 2013).

In line with these principles, the GoProForMED project implemented ecological networks within the target habitats, which are actively managed for timber production. The objective of the ecological network is to create a permanent system for the preservation of biological diversity and natural dynamic processes that maintain the vitality and functionality of the project's target habitats. This approach integrates several objectives of forest management, in particular the conservation aspect, fire risk prevention, to be reconciled with the production aspect.

The ecological network, located in the forest matrix, consists of Core Areas, Biodiversity Islands and Habitat Trees. For a description of the planning, characterisation and materialisation of the ecological network, please refer to the "Core Areas identification protocol" (version updated to 10.07.2024) and to the "*Biodiversity Islands and Habitat trees identification protocol"* (version updated to 23.07.2024).

In brief:

- **Core Areas (CA)** are areas characterised, in relative terms with respect to the forest stand, by a high functional and qualitative value for the conservation of biodiversity, which constitute the nodes of the ecological network. The function of the Core Area is that of a biodiversity hotspot and of a source of diffusion of mobile species;
- **Biodiversity Islands (IB)**, within the project, are connecting areas between the Core Areas. The IBs may already present conditions of high structural complexity (in terms of large trees, tree microhabitats, deadwood at different dacey stages, open areas, etc.) and thus contribute to increasing the degree of naturalness of the forest system, and to improving the overall conditions necessary for the conservation of biodiversity;
- **Habitat Tree (HT)**, within the project, have the function of stepping stones to strengthen the connection between IBs and Core Area.

In the logic of the project, the Core Areas are considered as biodiversity hotspots, to be destined for natural evolution. No intervention is therefore planned.

On the other hand, the Biodiversity Islands, having been selected mainly on the basis of spatial criteria, have varying ecological starting qualities.

The aim of the document is to illustrate the approach, methods and types of intervention to maintain or improve the structural complexity of IBs.

The interventions proposed for IBs take into account the natural dynamics of ecosystems and aim to favour the formation of mature and complex forest communities that support high specific biodiversity. This silvicultural approach considers the characteristics and role of each tree in the context of the natural dynamics of the forest.

3. The ecological network in Montes Forest

For the identification of the Core Area in the Montes project area, the following documents were analysed:

- Detailed Forest Plan of the "Supramonte" Forest Complex - UGB "Montes"
- Management Plan of SCI ITB022212 "Supramonte di Oliena, Orgosolo e Urzulei – Su Sercone"
- Nature Map of the Region of Sardinia, scale 1:50,000 (ISPRA)
- Satellite photo (Google satellite)
- Sardinia Region WMS services (Monumental trees, boundaries of the National Parks of Sardinia)
- Historical orthophotos

Firstly, the portion of habitat 9340 indicated in the project area (Grant Agreement, cartographic annexes), which falls within the property of the beneficiary FORESTAS Agency, was identified.

To this end, the data of the Detailed Forest Plan of the "Supramonte" Forest Complex - UGB "Montes" were cross-referenced with the data of the official Nature Map of the Region of Sardinia, where the extension of the forest habitats is shown (Figure 1).

Through this operation it was possible to select the surface area occupied by habitat 9340 - *Quercus Ilex* and *Quercus rotundifolia* forests, within the project area and the property of "Ente Foreste della Sardegna", which corresponds to approximately 1600 hectares.

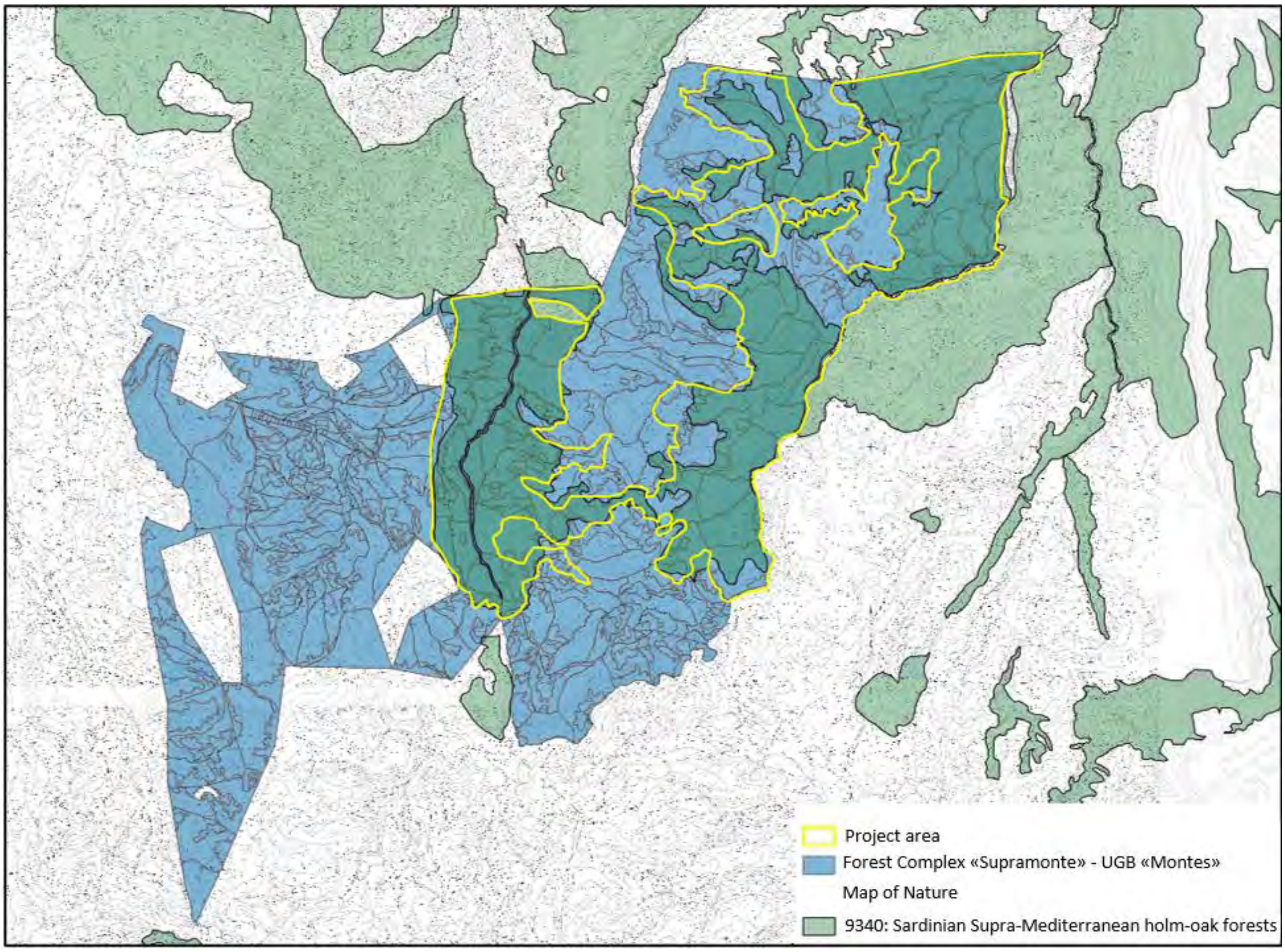


Figure 1. Cross-reference of the Map of Nature information for habitat 9340 with the boundaries of the Montes forest complex with focus on the Project Area

Based on the criteria described in the protocols for the identification of Core Areas and Biodiversity Islands, a single area of 1,121 ha was identified as the Core Area and 22 Biodiversity Islands with a total area of 34 ha.

	Quantity	Surface (ha)
Biodiversity Islands	22	34
Core Area	1	1.121
Edge area	-	460
		1.615

Minumum surface	0,91 ha
Maximum surface	1,55 ha
Average surface	3,19 ha

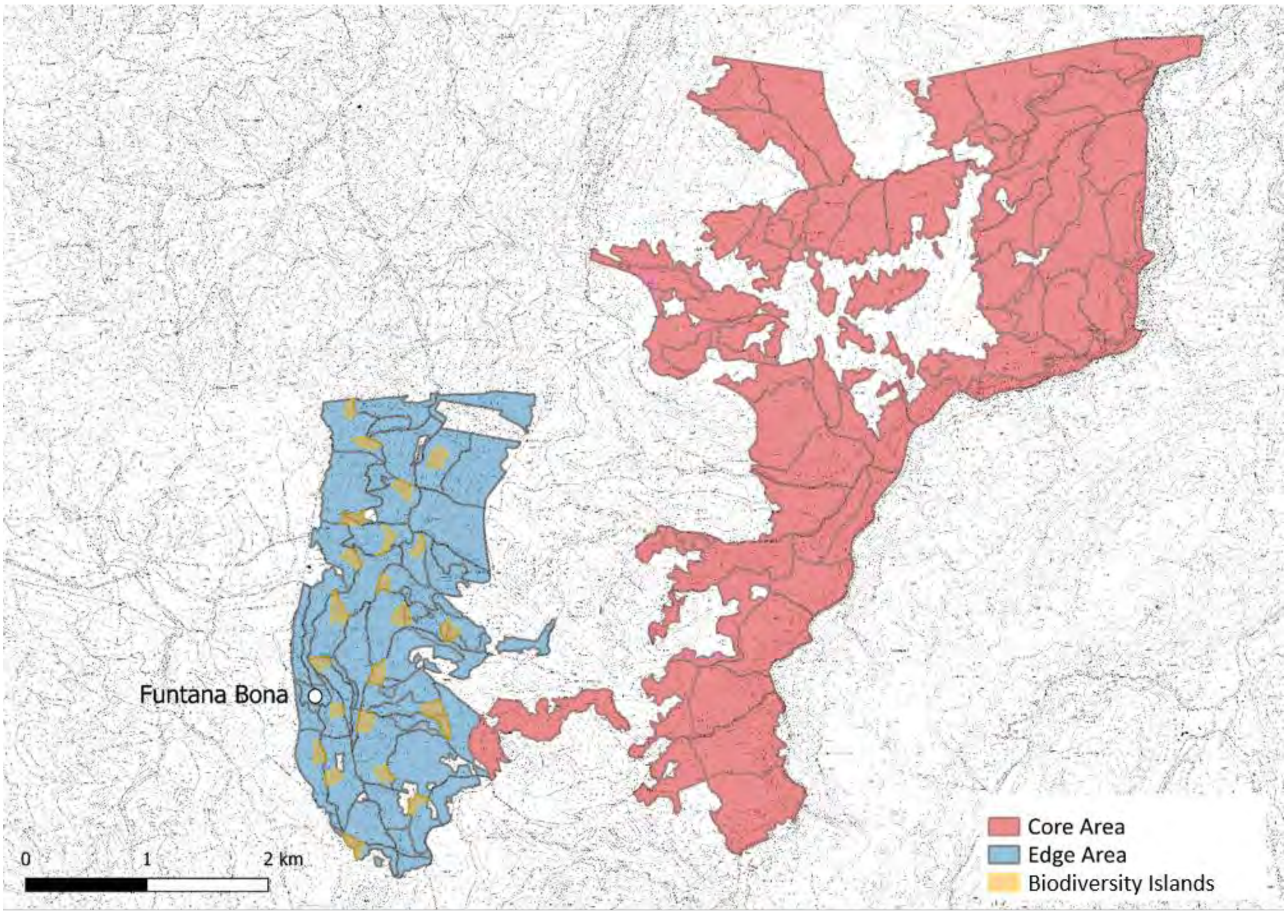


Figure 2. Project area divided by Core Area, Edge Area and Biodiversity Islands

At present, 20 out of 22 islands have been characterised through IBP and dendrometric surveys according to the methodology described in the "Protocol for the Identification of Islands for Biodiversity and Habitat Trees".

The summary results of the surveys carried out are reported below

Table 1. Summary of fixed radius (20m) test plots for each Biodiversity Island (IB) and list of forest plots involved

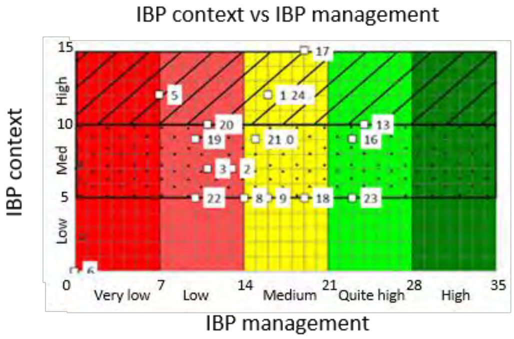
IB	Sur. (ha)	SF_1	SF_2	SF_3	Average DBH	Average height	Max height	n/ha	G/ha	V/ha
1	1,3	123/1	-	-						
2	1,3	124/1	-	-	19,0	11,3	13,6	827	27	162,7
3	1,5	128/4	-	-	23,4	11,9	14,3	835	41	261,2
4	1,3	128/2	-	-	18,0	11,2	13,5	1360	37	219,2
5	1,9	125/1	-	-	15,6	10,6	13,5	1806	38	215,3
6	1,5	125/1	-	-						
7	3,2	108/1	108/2	-	15,5	10,2	14,7	2204	52	304,6
8	0,9	104/1	-	-	21,1	11,6	15,2	827	35	224,1
9	1,3	104/2	-	-	20,9	11,7	14,7	994	38	236,0
10	2,1	103/1	-	-	20,6	11,0	14,8	1623	68	431,5
11	1,8	107/1	-	-	18,5	11,1	13,9	1153	36	217,6
12	1,6	88/1	88/3	-	21,2	11,6	15,8	1034	45	293,9
13	1,9	88/1	88/2	106/1	16,0	10,2	15,5	1352	41	261,8
16	1,1	85/2	-	-	17,8	10,7	15,6	1320	42	259,2
17	1,1	85/1	-	-	17,0	10,8	15,3	1281	36	224,1
18	1,2	82/1	-	-	24,1	11,9	14,8	660	35	230,7
19	1,6	82/1	57/1	-	21,0	10,9	14,2	891	36	218,3
20	1,5	81/1	-	-	20,4	11,1	22,0	1209	46	287,5
21	1,5	57/1	-	-	19,4	11,1	14,3	851	32	204,1
22	1,9	59/1	-	-	24,2	11,9	14,0	756	38	243,7
23	1,4	46/1	-	-	15,3	10,4	15,9	1519	35	212,5
24	1,0	46/1	-	-	30,2	12,2	17,2	485	54	402,8

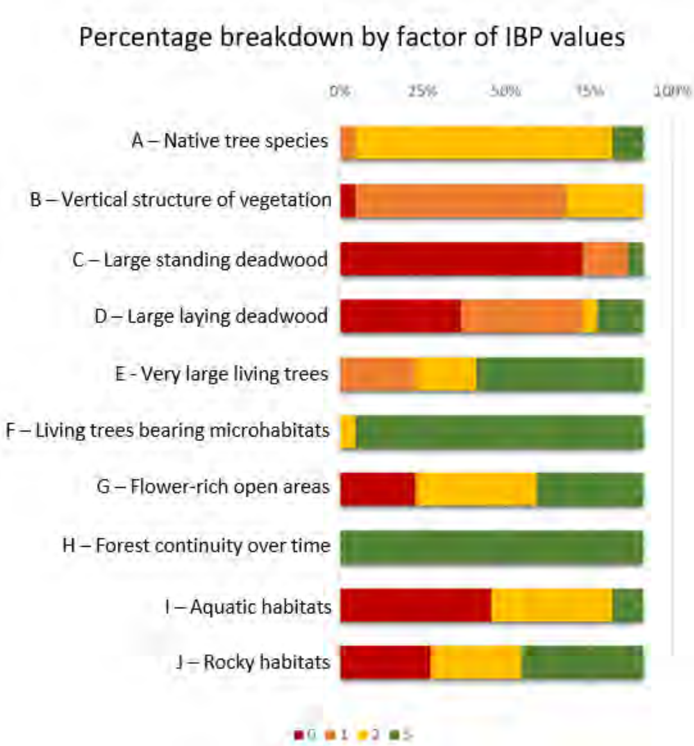
Table 2. Summary of IBP surveys for each IB. MAN = sum of 7 management factors, CONT = sum of 3 context factors

IB	A	B	C	D	E	F	G	H	I	J	MAN.	CONT.	IBP TOT
1													
2	2	1	0	1	2	5	2	5	0	2	13	7	20
3	2	0	1	0	1	5	2	5	2	0	11	7	18
4	2	1	0	0	5	5	5	5	2	5	18	12	30
5	2	1	0	0	0	2	0	5	2	5	5	12	17
6													
7	2	2	0	0	1	5	2	5	0	5	12	10	22
8	2	2	0	0	5	5	0	5	0	0	14	5	19
9	2	1	1	2	5	5	0	5	0	0	16	5	21
10	5	1	0	1	2	5	2	5	2	2	16	9	25
11	2	2	0	5	5	5	5	5	0	5	24	10	34
12	1	2	1	0	5	5	2	5	2	5	16	12	28
13	2	1	5	1	5	5	5	5	0	5	24	10	34
16	2	1	0	5	5	5	5	5	2	2	23	9	32
17	2	1	0	1	5	5	5	5	5	5	19	15	34
18	5	1	0	1	5	5	2	5	0	0	19	5	24
19	2	1	0	1	1	5	0	5	2	2	10	9	19
20	2	1	0	0	1	5	2	5	0	5	11	10	21
21	2	1	0	1	1	5	5	5	2	2	15	9	24
22	2	1	0	0	2	5	0	5	0	0	10	5	15
23	2	1	0	5	5	5	5	5	0	0	23	5	28
24	2	2	0	1	5	5	2	5	5	2	17	12	29

The graph on the right shows the summary of the IBP surveys carried out in the Biodiversity Islands and compares the management and context IBP recorded in each IB.

Most of the surveys are in the middle range for both the management and context IBP value





The graph on the left shows the percentage distribution of IBP values obtained in all the surveys carried out, factor by factor.
From the results obtained, the low presence of dead wood is evident in most cases. In fact, large standing and ground dead wood is totally absent in more than 70% of the Biodiversity Islands.

Although most of the stands surveyed are at a young developmental stage, the E-factor concerning the presence of large trees generally registers good values. This may be due to the traditional management of these forests, which often involved the release of isolated trees for acorn production, which are often still present as sporadic elements.

4. Silvicultural Objectives for Islands for Biodiversity

On the basis of the foreword, silvicultural objectives for the Biodiversity Islands are to favour an appropriate amount of large trees, habitat trees, open areas with floriferous herbaceous or shrub species, large deadwood at different decay stages and a high specific and structural diversity.

Interventions are designed in such a way as **to initiate or consolidate natural processes** that are considered to be significant in fostering the function of Biodiversity Islands as stepping-stones.

If a Biodiversity Island has already these characteristics, it is left to evolve freely, possibly only providing for interventions aimed at favouring the creation of new deadwood, in order to ensure the presence of different stages of decomposition.

However, if these areas lack the above-mentioned characteristics, interventions are planned with the following **objectives:**

OB1. Aim for a structure of maximum theoretical functionality

OB2. Promoting the presence of Very Large Trees (VLTs)

OB3. Favour the presence of habitat trees

OB4. Favour the specific diversity of the forest

OB5. Favour a heterogeneous vertical structure

OB6. Favour the presence of open areas and flowering herbaceous and shrub species

OB7. Increase the amount of laying and standing deadwood

The objectives listed above are detailed below, and for each one the management tools that can be used to achieve them are indicated.

OB1. Aim for a structure of maximum theoretical functionality. **The H model** (Simini et al., 2010, Anfodillo et al., 2013) represents an application of the allometric approach that makes it possible to quantify how far the current structural condition of the forest deviates from the theoretical maximum functional condition. The model represents a general and universal tool, applicable to all forests (BOX1).

According to this model, it is possible to estimate the diametric distribution of a stand capable of optimising resources in the same way as in a forest with advanced natural characteristics. The interventions implemented by the project aim to orient the stand towards a more complex structure, represented by the reference diametric distribution derived from the model for each of the 4 target habitats.

In order to make this criterion more understandable and easier to apply, reasoning on structure is carried out on the basis of 4 size categories:

Categories	Saplings	Poles	Large	Very large
Diameter classes (cm)	10-15 (7,5-17,5)	20-35 (17,5-37,5)	40-55 (37,5-57,5)	60 + (>57,5)

Young trees, referred to as "Saplings", are small to medium-sized trees belonging to the 10 and 15 diameter classes. Together with "Poles" (medium-sized trees belonging to the 20 to 35 diameter classes), they are considered the dynamic portion of the forest. They are in fact represented by plants that can be most influenced by silvicultural interventions for their future development.

As far as medium-large plants, defined as "Large", are concerned, it is possible to plan targeted interventions on them to increase the quantity of large deadwood. However, since we are dealing with plants of considerable size, which are often scarcely present in Mediterranean forest contexts, the planned interventions will be punctual so as not to further damage this cathegory.

Finally, for plants belonging to the "Very Large" category (DBH>60cm), conservation is envisaged, as they normally have a high intrinsic landscape and ecological value.

From the comparison between the reference diametric distribution obtained from the H Model and the actual stand distribution, deriving from the characterisation of the Biodiversity Islands carried out by means of structural surveys, it is possible to determine the characteristics of the intervention in terms of the number of plants per hectare to be cut or ring barked.

This is done by identifying the supernumerary and subnumerary size categories with respect to the reference distribution and by acting on the supernumerary plants through cutting or ring barking and conserving or favouring the plants belonging to the diametric classes that are not sufficiently represented. In general, it is advisable to select the largest individuals belonging to one size class if the next size class is subnumerary with respect to the reference model.

In the case of stands in which the Saplings class is deficient in terms of number of individuals, the intervention should facilitate the initiation of renewal processes or the renewal nuclei already present.

BOX 1 – The application of the H Model in the Montes Forest

Within a forest, the assemblage of trees of different diameters is the result of birth and mortality processes occurring over space and time and constitutes the so-called forest structure. This, from an ecological point of view, is an important attribute of the community.

From a theoretical point of view, it is possible to predict, using the tools of statistical mechanics with a simplified system, the size distribution of the individuals in a community capable of optimising the use of resources (light, water or other) similar to what happens in a state of forest ageing.

The H-model consists of a universal allometric model capable of predicting the diametric distribution curve of a forest that is virtually capable of using all available resources, assuming that each individual consumes resources in relation to the size of its canopy. Such a distribution indicates the optimal structure of a forest close to maximum functional conditions.

Within the framework of LIFE GoProFor Med, it is planned to implement the model in the 4 target forest habitats, in order to determine the reference distribution characteristic of each of these.

In June 2023, the pilot application of the H-model was carried out in the project site of Montes (NU, Sardinia, Italy), which will be valid for the habitat 9340 –*Quercus ilex* and *Quercus rotundifolia* forests (Protocol for the definition of the degree of disturbance in Mediterranean forests - Model H of deliverable D3.1 - Technical and operational methodological report for the conservation improvement of the 4 target habitats).

The aim of the application was to derive the **current structural model** of the analysed forests and the **potential model** valid for all forests belonging to habitat 9340.

From the resulting potential model, it is possible to derive the potential diametric distribution (Fig. 1), which will be taken as a reference in the implementation of the interventions within the Biodiversity Islands (OB.1).

Categories	Saplings	Poles	Large	Very large
Diametric classes (cm)	10-15 (7,5-17,5)	20-35 (17,5-37,5)	40-55 (37,5-57,5)	60 + (>57,5)
Potential diametric distribution	53%	36%	8%	3%

Figure 3. Potential diametric distribution for habitat 9340 - Quercus ilex and Quercus rotundifolia forests

OB2. Promoting the presence of Very Large Trees (VLTs). The term 'Large Size Trees' (VLTs) refers to the IBP definition for Mediterranean areas (Emberger et al., 2016), i.e. living trees with a diameter >57.5cm. Large trees play an extraordinary range of crucial ecological roles, influencing the hydrological regime, nutrient cycling and numerous other eco-systemic processes (Lindenmayer & Laurance, 2016). They also play a crucial role for a wide range of plant and animal species due to their microhabitats, size and large canopies, which offer shelter, food and breeding sites for many species, particularly epiphytic species and cavity-nesting birds and bats (Mollet et al., 2013; Hofmeister et al., 2015), thus contributing to forest biodiversity (Emberger et al., 2016).

Firstly, in order to guarantee this objective, it is necessary to preserve the existing large trees (belonging to the 'Very Large' category). In addition, in order to increase their share, an intervention is applied that involves the candidature of a certain number of trees in order to encourage their growth. This intervention is configured as a selective thinning of an extensive nature in the case of young stands, or as a tree-oriented silviculture intervention, and therefore more punctual, in the case of stands characterised by a more advanced evolutionary stage.

As elite trees, a number of plants belonging to the "Poles" or "Large" categories, defined by the number of plants that can be cut or ring barked according to the reference H model, must therefore be selected in order to rebalance the natural potential distribution. Benefiting from an increased availability of light, water and nutrients, these plants have the opportunity to react to their release by expanding their canopy and accelerating their growth rate in a timely manner.

Some criteria on the characteristics of the elite tree:

- In the selection of elite trees belonging to the Poles category, trees with a good mechanical stability index (H/DBH ratio<80) with a good crown depth (1/3 of the height) and with an uncompressed crown and a balanced shape are recommended;
- In the selection of elite trees belonging to the Large category, the main criterion is membership of the diametric class and the presence of actual competing trees;
- In specific cases where groups of two or more trees are identified that concur in defining a unit of value (e.g. a Large tree and one or more elite Pole trees), it is advisable to define the elite trees taking into account the reciprocal relationships and subsequently working in favour of the entire group;
- In general, the choice of elite trees must take into consideration a share represented by minority species (see OB.4), as long as they are capable of becoming large, the identification of native trees located in significant spatial positions (e.g. near open spaces, in particular edaphic conditions).

OB3. Favour the presence of habitat trees. Within the project a Habitat Tree (HT) is defined as "a standing living tree that, in its current state, bears either":

- at least one tree microhabitat (TreM) listed in a list of TreMs identified as “priority” (BOX 2), or
- at least one TreM found to be among the least frequent at site level, or
- at least 3 different TreMs

Habitat Trees are considered of primary importance for forest biodiversity, as they provide ecological niches (tree microhabitats) for sometimes highly specialised forest flora and fauna for at least part of their life cycle (Bütler et al., 2013; Bütler et al., 2016; Directora-te-General for Environment, 2023). Correctly identifying, protecting and managing these trees is essential for preserving the ecological function and structural complexity of forests in the long term.

BOX 2 – Tree microhabitat

Definition (TreM): a distinct, well delineated structure occurring on living or standing dead trees, that constitutes a particular and essential substrates or life site for species or species communities during at least a part of their life cycle to develop, feed, shelter or breed (Larrieu et al. 2018).

Priority TreMs types
Grouped into the 7 forms identified da Bütler et al. 2020, following Larrieu et al. 2018.
All seven types are represented by at least one microhabitat.

1) **Cavities:**
   - Woodpecker “Flute”
   - Trunk-base rot-hole (closed top, ground contact)
   - Trunk rot-hole (closed top, no ground contact)
   - Semi-open trunk rot-holes
   - Chimney trunk-base rot-hole (in contact with the ground)
   - Chimney trunk rot-hole with no ground contact
   - Bark-lined trunk concavity
   - Hollow branches
2) **Injuries and exposed wood:**
   - Lightning scar
   - Fire scar
   - Bark shelter
   - Bark pocket
   - Crack
   - Fork split at the intersection
3) **Crown deadwood:**
   - Dead top
4) **Excrescences:**
   - Burr
   - Canker
5) **Fungal fruiting bodies and slime moulds:**
   - Perennial polypore
   - Annual polypore
   - Pulpy agaric
   - Large pyrenomycete
6) **Epiphytic and epixylic structures:**
   - Bark microsoil
   - Invertebrate nests
7) **Fresh exudates:**
   - Sap run

Given that in the course of the intervention the utmost attention must be paid to habitat trees, identifying them and assessing their current and potential effectiveness, selective thinning can also be carried out in favour of habitat trees. This is done with the aim, for example, of guaranteeing a longer survival period or to determine structural diversifications of the stand hinged on their presence. Thus, intervention can be envisaged against the direct competitors of subjected/dominated habitat trees in order to favour their viability by reducing competitors, or to free fractions of deadwood in the canopy in order to increase the degree of illumination, or, again, to strongly reduce the density of the forest in contiguity with TreMs-rich habitat trees that are home to birds or bats, so as to make them more favoured by these species.

In addition, the analyses carried out in WP02 of the project showed that there is a potential connection between habitat trees and plants that, in the previous cropping cycle, acted as 'standars'. Therefore, it is recommended that these trees also be included among the target plants, even if they are not currently classified as habitat trees. These trees are to be considered as potential habitat trees and, therefore, silvicultural interventions can be envisaged for them in order to favour their vitality and permanence in the forest.

OB4. Favour the specific diversity of the forest. Tree species composition of forest stands have been shown to be key drivers of forest-associated biodiversity in several studies (Penone et al., 2019; Ampoorter et al., 2020). Specific diversity ensures a wider variety of fruits, seeds, flowers and foliage available as food sources for wildlife (Emberger et al., 2016). Furthermore, many studies have provided ample evidence that trees biodiversity can influence key ecosystem processes such as biomass production, nutrient cycling and pest regulation (Cardinale et al., 2012; Emberger et al., 2016). Finally, there is a positive relationship between specific diversity and resilience, with more diverse systems exhibiting less disturbance-induced variability (Silva et al., 2015).

In order to encourage a specific mix in the stand, all trees belonging to sporadically present species must be released. Furthermore, in the case of trees belonging to these species characterised by good vigour, these can be favoured through selective thinning.

OB5. Favour a heterogeneous vertical structure. Forest stands naturally present a range and complexity of structural factors, including size and diametric diversity of trees and vertical structure (Mansourian et al. 2013). The diversity and development of vertical strata closely influence forest biodiversity, creating diverse ecological conditions and niches that are preferentially used by different plant species, animals and microorganisms (Puumalainein, 2001; Basile et al., 2016; Emberger et al., 2016).

In order to favour an articulated vertical structure, the intervention in favour of the selected elite trees should be a thinning from above, acting against the dominant competitors or in the same plane of the crowns and keeping the dominated layer unaltered. When there are minor species that tend to occupy the lower dominated layers, it may be useful to concentrate the reduction in density in the dominant plane for small stretches so as to create an irregularity of cover in the forest that induces the residual plants to occupy the spaces created with their foliage.

OB6. Favour the presence of open areas and flowering herbaceous and shrub species. Open areas in forests increase the landscape diversity by influencing the composition and abundance of insect species (De Groot et al., 2016). Forest species facultatively utilise these gaps for food resources, due to an increased presence of blooms, or cluster there for reproduction (Chiari et al., 2013; Emberger et al., 2016; Gittings et al., 2006; Hardersen et al., 2012). Large open areas are crucial for increasing biodiversity, while smaller areas are preferable for preserving species (De Groot et al., 2016).

Ensure the presence of open areas totalling 200-400 m^2/ha, possibly distributed in two units, in order to favour the entry of light into the soil and the development of flowering herbaceous or shrub species. This value is to be considered gross of existing open areas.

The opening up of gaps is a disturbing element with respect to the ecosystem that must be generated with as little impact as possible by carefully choosing the points from which to generate these environments (e.g. by choosing areas in which the presence of herbaceous species is already indicated, even if in small quantities). It is advisable, for example, to widen existing margins, or to realise a reduction of tree canopies in the vicinity of rocky areas, or even to start from a small gap in the canopy cover and progressively widen it in the direction of the light source.

In the case of closed stands, it is advisable to create a crown gap of a maximum of 100 m2 and to carry out a series of thinnings of lesser intensity around it in order to maximise the light gradient on the ground.

If allochthonous species are present, it is advisable to carefully assess the feasibility of this type of intervention in order to avoid creating favourable conditions for the proliferation of these species.

It is also advisable to avoid the opening up of clearings in young stands, as the intervention could result in the regrowth of stumps rather than the entry of flowering herbaceous species.

OB7. Increase the amount of laying and standing deadwood. It is estimated that between 20 and 40% of forest plants, animals and fungi depend on dead or dying wood in at least one stage of their life cycle (Bauhus et al. 2019, Emberger et al. 2016). Maintaining different qualities of deadwood in terms of tree species, diameter, decay class and type (standing or laying) has a positive effect on the conservation of saproxylic species communities (Lachat et al., 2013). Furthermore, deadwood is not only recognised as a key element for saproxylic species, but is also known for its important function in nutrient release and water retention (Lachat et al., 2013). Regarding the size of deadwood, larger sizes have been identified as essential for the conservation of saproxylic species, for several reasons: being more heterogeneous they offer more ecological niches and microhabitats, which in turn influence the diversity of saproxylic species (Lachat et al. 2013); size influences the stability of microclimatic conditions and the availability of the resource, as large deadwood decomposes more slowly, remaining available for longer, influencing larval development and ensuring the development of different stages of decomposition (Gossner et al., 2013; Motta, 2020); large standing deadwood is important for bats and birds, which exploit these structural elements for feeding and nesting or roosting (Rigo et al., 2024); furthermore, large elements are normally scarce in managed forests, and it becomes crucial to preserve them (Gossner et al., 2013, Lachat et al., 2013).

Within the project, a **minimum diametric threshold of at least 17.5 cm** is considered (Emberger et al., 2016) and **a target quantity of deadwood of at least 20 m^3/ha** (Micò et al., 2022) is aimed for, gross of existing deadwood and taking into account the intervention limits determined by the application of the forest's potential natural distribution (OB.1) and the impact limits imposed for each size category (see section 3).

The planned interventions in the Biodiversity Islands do not involve wood extraction. All plants marked with DBH >17.5 cm will be added to the quota of useful deadwood. However, when performing the trees selection, it is advisable to manage the cuts and ring barking in such a way as to differentiate the release as much as possible in terms of material density (accumulation of trees and individual trees), lighting (in light and shade), humidity (in valleys or in bumps), spatial (favouring concentration over regular distribution), and type (standing and laying).

Ring barking (BOX 3) may be carried out in cases where it is deemed more appropriate to eliminate the competitor tree through a process of decay that, depending on the technique used, may be slower or slower than cutting and felling.

This choice avoids the compromise of the elite tree due, for example, to its abrupt release and consequent destabilisation. Ring barking can also be a valid alternative in cases where cutting and felling the competitor tree entails a high risk of damaging the elite tree.

This technique can also be applied on fairly large trees that are already senecent, in order to accelerate the decay process.

In the vicinity of frequented areas (recreational areas, tracks, paths, etc.), where the presence of standing dead trees could pose a risk to the safety of those who frequent the forest, it will be advisable to cut and release of the tree on the ground.

For trees intended for cutting to increase the amount of laying deadwood, it is possible to envisage cutting the tree at a height of 1 m, in order to differentiate as much as possible the types of deadwood released and to hinder any erosive processes.

BOX 3 – Types of ring barking

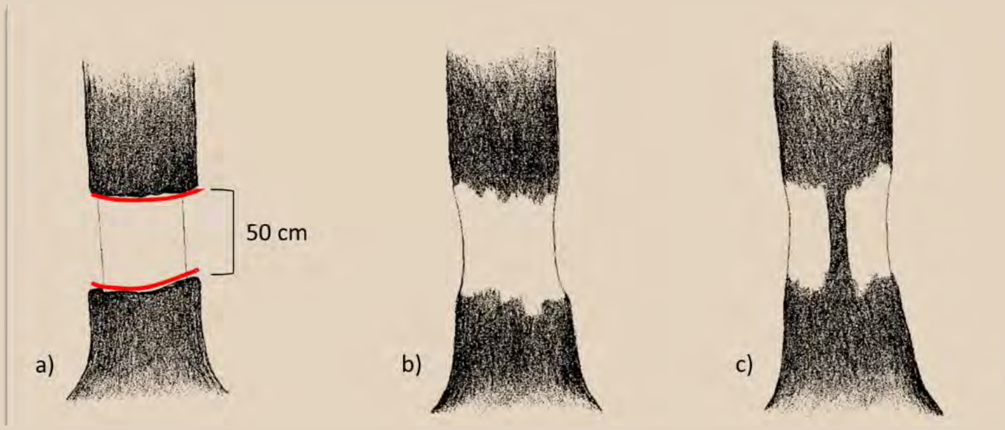
Ring barking consists of removing the outer layers of a portion of the trunk (outer bark and phloem) down to the *cambium*, with the aim of limiting the development and reproduction capacity of the ring barked individual by inducing a slow process of decay.

The main recommended techniques are described below:

a) **Deep ring barking**: this consists of using a chainsaw to make two ring cuts around the trunk in the basal part of the stem, 4-5 cm deep and about 50 cm apart, and removing the entire portion of the trunk with equal thickness to the depth of the cut, present between the two cuts. This type of rink barking causes the plant to decay faster than the two techniques described below.

b) **Superficial ring barking**: this consists of removing a ring of approximately 50 cm in height of the superficial tissues (outer bark and phloem) only. This type of ring barking can be carried out using a billhook or a manual debarker.

c) **Partial ring barking**: this consists of a superficial ring barking with the release of an intact connection strip of the superficial tissues (outer bark and phloem). In this way, the process of decay is further slowed down compared to types a) and b)



5. Intensity of interventions

The intensity of intervention may vary on each Biodiversity Islands, depending on its existing structure and ecological conditions.

On Biodiversity Islands that represent mature stands with good ecological conditions, the intensity of intervention will be reduced to a minimum in order to conserve existing conditions. Punctual interventions may be envisaged when necessary in order to achieve one of the 7 objectives.

A higher intervention intensity can be envisaged for Biodiversity Islands where the population volume is more concentrated in the Poles groups. However, in order to avoid destabilising the stand from a structural point of view, the intervention should take into account the following **maximum impact limits**:

- **25-30% of the number of Saplings**
- **25-30% of the number of Poles**
- **15% of the number of Large**

With regard to stands characterised by a young evolutionary stage, mostly represented by individuals belonging to the Saplings group, it is considered too premature to intervene extensively. In this case, punctual interventions can be envisaged with the specific aim, if necessary, of favouring the larger plants and habitat trees present.

Table 3. Summary table of the types and intensity of intervention envisaged according to the structural characteristics of the stand

Stand characteristics	Intervention intensity	Actions
Mature stands, articulated structure Population volume is more concentrated in the 'large' and 'very large' categories		Preservation of current conditions. Punctual tree-oriented silviculture interventions aimed at achieving Ob. 1-7
Regularly structured adult stands or irregularly structured young-adult stands; Population volume is more concentrated in the “poles” category		Selective thinning to achieve Ob. 1-7 Impact limit on the number of Saplings: 25-30% Impact limit on the number of Poles: 25-30% Impact limit on the number of Large: 15%
Regularly structured young stands; Population volume is more concentrated in the “saplings” category		Ensure the conservation of all habitat trees and larger plants. Punctual tree-oriented silviculture interventions only when necessary to favour larger plants and habitat trees (OB2 and 3).

As a suggestion, the number of tree to select can be derived from a comparison between the actual diametric distribution and the reference diametric distribution given by the H model, also considering the imposed impact limits of 20-30% for Poles and Saplings and 15% for Large.

The number of elite trees can be derived from the total number of trees to select, considering the removal of 1.5 competitor trees for each elite tree belonging to the "Poles" category and 2.5 trees for each elite tree belonging to the "Large" and "Very Large" categories.

Example of calculation (Fig. 2):

The calculation is carried out by comparing the actual population distribution with the reference potential distribution/ H Model. From this comparison, the supernumerary categories (in the figure in green) are identified and the percentage in excess of the model is derived. At this point, **impact limits** are imposed on the diametric categories, which are only applied if the percentages of supernumeraries are higher.

From the resulting percentages, the number of trees per hectare and the volume per hectare of the intervention are obtained.

At this point, if the amount of volume (to be released as deadwood) is too high, a further **upper limit on the amount of deadwood** to be released can be applied (to be agreed with the operator), from which the final number of trees per hectare to be cut or ring barked is also obtained.

Categories	Saplings	Poles	Large	Very large
Diametric classes (cm)	10-15 (7,5-17,5)	20-35 (17,5-37,5)	40-55 (37,5-57,5)	60 + (>57,5)
H Model %	53%	36%	8%	3%
Real distribution % (n/ha)	25% (207)	70% (581)	6% (48)	0% (0)
Supernumerary percentage	-	34%	-	-
Impact limits	**20%**	**20%**	**15%**	-
Hypothetical intervention according to impact limits (n/ha)	-	116	-	-
Hypothetical intervention according to impact limits (V/ha)	-	49	-	-
Deadwood limits		**20 m3/ha**		
Intervention characteristics				
Volume (m3/ha)	-	**20 (10%)**	-	-
N (n/ha)	-	**47 (8%)**	-	-

Figure 4. Example of the calculation of the volume and number of plants to be cut or ring barked. In this case, the intervention will consist of the selection of 47 plants/ha belonging to the "Poles" category for a volume of 20 m^3/ha.

6. Tree selection phase

At the moment, trees selection was carried out in Montes Complex according to the criteria described above in Biodiversity Islands Nos. 2, 5, 8, 11, 13.

During the trees selection, the diameter of the trees to be felled or ring barked and the reason for their selection were recorded on a special “trees selection sheet”.

It should be noted that for this type of intervention there is no wood extraction, and that the estimated volume of the intervention is to be considered as the volume of deadwood released in the forest.

6.1. Symbols used for trees selection

During the tree selection, the Biodiversity Islands were delimitated by marking boundary trees (trees outside the Island). identification of the boundary trees was carried out with a GPS system.

The marking of the boundary trees was carried out with a horizontal band in blue paint, placed approximately 1 - 1.5 m high. The marks are made in such a way that they are intervisible with each other (approximate distance 20-30 m).

Within the Biodiversity Islands, the trees to be released as elite trees, identified with a fluorescent orange stamp at breast height, and as habitat trees, marked with an orange triangle pointing downwards, are selected.

Trees to be felled or ring barked, on the other hand, are marked with fluorescent yellow paint with a vertical line along the stem for the former and with a vertical line and a ring at the base for the latter.

Tree to be cut and released to the ground

Tree to be ring barked

Elite tree

Habitat tree

6.2. Summaries of tree selection

6.2.1. Biodiversity Island n. 2

Diametric class	n. trees/ha	Aver. H (m)	G (mq/ha)	Volume (mc/ha)
20	25	11,7	0,77	4,78
25	18	12,4	0,88	5,77
30	7	13,0	0,50	3,42
35	1	13,3	0,09	0,59
TOT.	**51**	**12,17**	**2,23**	**14,6**

	ANTE	INTERVEN-TION	POST	INTERVENTION %
n/ha	828	51	777	6%
G (mq/ha)	26,69	2,23	24,45	8%
Volume (mc/ha)	172,09	14,60	157,49	8%

Target deadwood vol.: 20 mc/ha				
	INTERVENTION		PRE-EXISTING	TOT
Tot	**14,6**	**8,5%**	**1,3**	**15,9**
Laying	*9,0*	*5%*	*1,3*	*10,4*
Standing	*5,6*	*3%*	*0,000*	*5,5*

6.2.2. Biodiversity Island n. 5

Diametric class	n. trees/ha	Aver. H (m)	G (mq/ha)	Volume (mc/ha)
10	5	10,1	0,05	0
15	13	10,8	0,23	0,00
20	10	11,6	0,30	1,85
25	8	12,4	0,37	2,42
30	1	12,8	0,06	0,41
TOT.	**37**	**11,3**	**1,01**	**4,68**

	ANTE	INTERVEN-TION	POST	INTERVENTION %
n/ha	1806	37	1769	2%
G (mq/ha)	38,10	1,01	37,09	3%
Volume (mc/ha)	231,54	6,35	225,19	3%

Target deadwood vol.:		**0,0**	**mc/ha**	
	INTERVENTION		PRE-EXISTING	TOT
Tot	**4,688**	**2,0%**	**0,000**	**4,708**
Laying	*2,138*	*1%*	*0,000*	*2,147*
Standing	*2,550*	*1%*	*0,000*	*2,561*

6.2.3. Biodiversity Island n. 8

Diametric class	n. trees/ha	Aver. H (m)	G (mq/ha)	Volume (mc/ha)
20	10	11,8	0,29	1,83
25	14	12,4	0,63	4,16
30	9	13,0	0,55	3,76
40	1	13,9	0,13	0,91
50	1	14,7	0,20	1,55
TOT.	**35**	**12,5**	**1,81**	**13,31**

	ANTE	INTERVEN-TION	POST	INTERVENTION %
n/ha	828	35	793	4%
G (mq/ha)	34,94	1,97	32,97	6%
Volume mc/ha)	234,61	13,31	221,30	6%

Target deadwood vol.:		**20,0**	**mc/ha**	
	INTERVENTION		PRE-EXISTING	TOT
Tot	**13,307**	**5,7%**	**0,294**	**13,658**
Laying	*6,236*	*3%*	*0,294*	*6,556*
Standing	*7,072*	*3%*	*0,000*	*7,102*

6.2.4. Biodiversity Island n. 11

Diametric class	n. trees/ha	Aver. H (m)	G (mq/ha)	Volume (mc/ha)
10	4	9,8	0,04	0,00
15	20	10,9	0,38	0,00
20	18	11,7	0,56	3,51
25	14	12,4	0,65	4,26
35	2	13,4	0,18	1,27
TOT.	**58**	**11,5**	**1,81**	**9,06**

	ANTE	INTERVEN-TION	POST	INTERVEN-TION %
n/ha	1154	58	1096	5%
G (mq/ha)	35,89	1,81	34,08	5%
Volume mc/ha)	230,23	11,50	218,73	5%

Target deadwood vol.:		**20,0**	**mc/ha**	
	INTERVENTION		PRE-EXISTING	TOT
Tot	**9,06**	**3,9%**	**1,31**	**10,42**
Laying	*5,09*	*2%*	*1,31*	*6,42*
Standing	*3,98*	*2%*	*0,00*	*3,99*

6.2.5. Biodiversity Island n. 13

Diametric class	n. trees/ha	Aver. H (m)	G (mq/ha)	Volume (mc/ha)
10	3	9,9	0,03	0,00
15	3	10,5	0,04	0,00
20	5	11,6	0,15	3,51
25	2	12,5	0,10	4,26
TOT.	**13**	**11,1**	**0,32**	**9,06**

	ANTE	INTERVENTION	POST	INTERVENTION %
n/ha	1353	13	1340	1%
G (mq/ha)	40,50	0,32	40,18	1%
Volume (mc/ha)	274,07	1,98	272,09	1%

Target deadwood vol.:		**4,3**	**mc/ha**	
	INTERVENTION		PRE-EXISTING	TOT
Tot	**1,57**	**0,6%**	**0,00**	**1,58**
Laying	*1,22*	*0%*	*0,00*	*1,22*
Standing	*0,35*	*0%*	*0,00*	*0,35*

7. Programme of Interventions

The following table shows the interventions in the Biodiversity Islands and the Continuous Cover Forestry interventions in the Demonstration Areas-AD (4 ha) envisaged by the project, to be implemented in 2024 (in grey) and 2025

Type of Area	ID	Surface (ha)	Year
IB	2	1,3	2024
IB	3	1,5	2024
IB	4	1,3	2024
IB	5	1,9	2024
IB	7	3,2	2024
IB	8	0,9	2024
IB	9	1,3	2024
IB	11	1,8	2024
IB	12	1,6	2024
IB	13	1,9	2024
IB	1	1,3	2025
IB	6	1,5	2025
IB	10	2,1	2025
IB	16	1,1	2025
IB	17	1,1	2025
IB	18	1,2	2025
IB	19	1,6	2025
IB	20	1,5	2025
IB	21	1,5	2025
IB	22	1,9	2025
IB	23	1,4	2025
IB	24	1,0	2025
AD	1	1,0	2024
AD	2	1,0	2025
AD	3	1,0	2025
AD	4	1,0	2025

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