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Improvement of the conservation status of forest habitats in the Mediterranean Biogeographical Region applying restoration and conservation techniques and *Close to Nature* management

Assessing the degree of disturbance with an allometric functional approach in the holm oak (*Quercus ilex*) forest of Montes (Sardinia, Italy)

Preliminary results 2023

WP2 - Assessment of the conservation status of target forest habitats

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MONTES FOREST

Tree species partitioning

From our field survey emerged that 95% of the trees of all diametric classes belong to the species *Quercus ilex* with a minority of individuals being *Juniperus oxicedrus* (1.95%) and *Rosmarinus officinalis* (1.1%) in the understory (Figure 1). The regeneration layer, i.e. trees less than 200 cm high including small seedlings which diameter is <1 cm, have a similar species share: helm oak *Quercus ilex* (85%; mean diameter 8.12 cm), *Juniperus oxicedrus* (5.4%; mean diameter 3.5 cm), *Rosmarinus officinalis* (5.4%; mean diameter 2.7 cm) and *Erica arborea* (1%; mean diameter 1.5 cm). Occasional species include: *Phyllirea latifolia; Erica arborea; Pinus pinaster; Acer monspessulanum; Rosa spp.; Taxus baccata.*

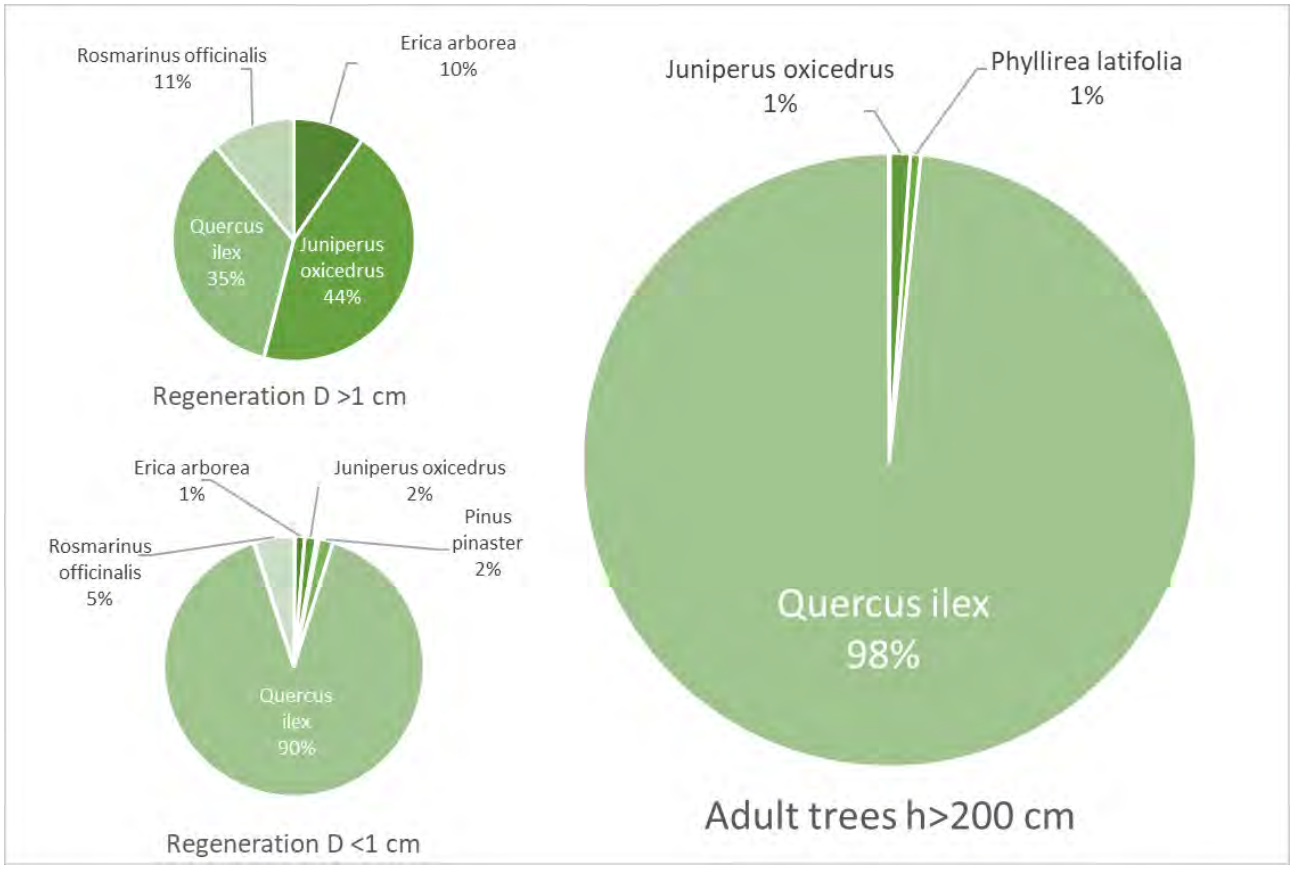

Figure 1. Species share in Montes Forest 2023.

Indeed, overall helm oak fill almost the totality of the basimetric area in the dominant layer. The tall regeneration higher than 200 cm is rather composed by a dominated understory of *Juniperus oxicedrus* which percentage (44%) is almost similar to that of helm oak in the regeneration stage (35%). Indeed, *Juniperus* protective spines create a protected nursery for oak seedlings preventing herbivore browsing. The same role, but less effective is carried out by *Rosmarinus* and *Erica* that tend to occupy as pioneers' most of the clearings. In the very small regeneration layer, we find a similar diversity of wood species, but helm oak is as pervasive as in the dominant layer with 90% of the individuals. Minor species are the same as listed in the regeneration with D >1 cm.

Area type	Threshold	Species	%	% main spp.
Relascopic Bitterlich n°1	h>200cm	*Erica arborea*	0.04	
	h>200cm	***Juniperus oxicedrus***	**1.06**	**1.06**
	h>200cm	*Phyllirea latifolia*	0.55	
	h>200cm	***Quercus ilex***	**98.32**	**98.32**
	h>200cm	*Taxus baccata*	0.04	
Transect 10 m²	>1cm	*Erica arborea*	0.87	
	>1cm	***Juniperus oxicedrus***	**4.06**	**4.06***
	>1cm	***Quercus ilex***	**3.19**	**3.19**
	>1cm	***Rosmarinus officinalis***	**1.01**	**1.01***
	<1cm	*Acer monspessulanum*	0.14	
	<1cm	*Erica arborea*	1.09	
	<1cm	***Juniperus oxicedrus***	**1.30**	**1.30***
	<1cm	*Phyllirea latifolia*	0.29	
	<1cm	*Pinus pinaster*	1.59	
	<1cm	***Quercus ilex***	**81.87**	**85.06**
	<1cm	*Rosa spp.*	0.14	
	<1cm	***Rosmarinus officinalis***	**4.43**	**4.43***

H-model comparison with field survey

The actual frequency distribution of tree number per D class in the site of Montes (grey triangular markers) is compared with the H-model distribution (red markers) derived from the modelling of the crown volume. In this case the cut-off is applied at a D = 75 cm (corresponding to a tree height of 20 m), while the maximum diameter on site reaches 220 cm. Black dots and trend line indicate the data distribution projected on the site considering D classes >11 cm, therefore without disturbance from grazing.

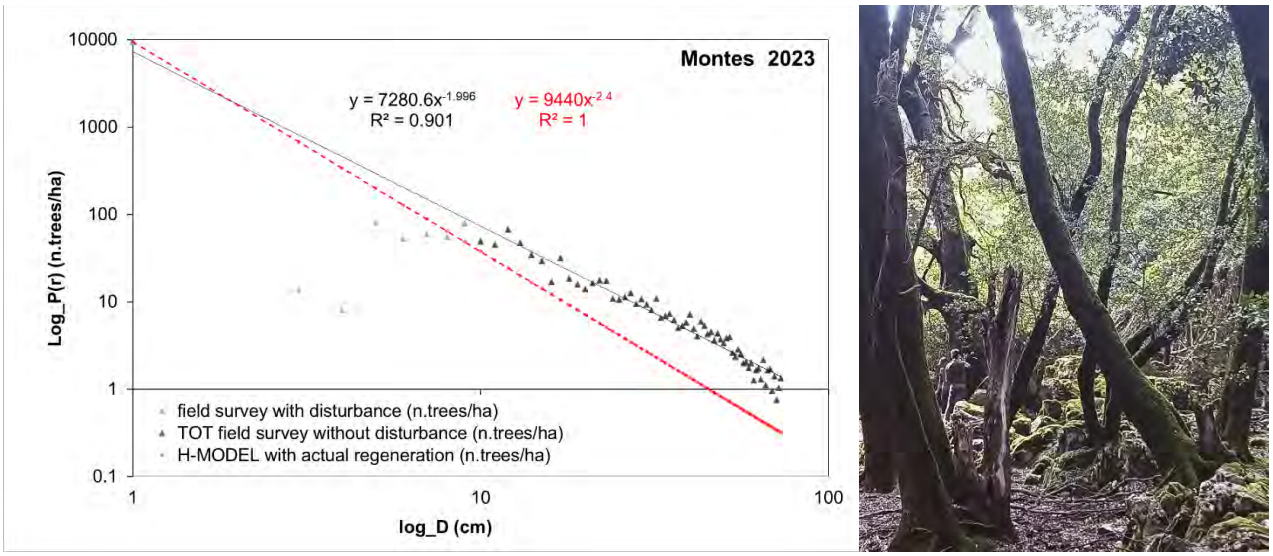

Figure 2. Comparison of the tree distribution in diametric classes at the field survey and according to the H-model by keeping the regeneration number at the survey as a reference in Montes Forest 2023.

However, we cannot assume that the regeneration is at its maximum potential. Therefore, we hypothesize that within the present situation the forest is actually using its resources at its maximum potential, though not well distributed in the diametric classes.

Predicted distribution with conservative crown volume approach

The gross primary production of the forest depends on the carbon fixation of the crowns, which are a proxy of the available resources: solar radiation, water, nitrogen. At the field survey crowns amount to a volume equal to 101668 m^3 per hectare. This crown volume can also be reached with a different diametric distribution in order to respect the tree mortality and the exponent of the H-model. To achieve this target, we calculated that the ideal regeneration D <1 shall be of 32.786 seedlings/ha.

In Figure 3 is shown the result of the distribution with the redistributed crown volume according to the H-model. There the slope of -2.44 described by the H-model is respected but also all the tree number per class per hectare is calculated in order to conserve the actual cumulative crown volume of the population. Here after this version of the H-Model will be referred as "HMCC", H-Model Conservative Crown volume.

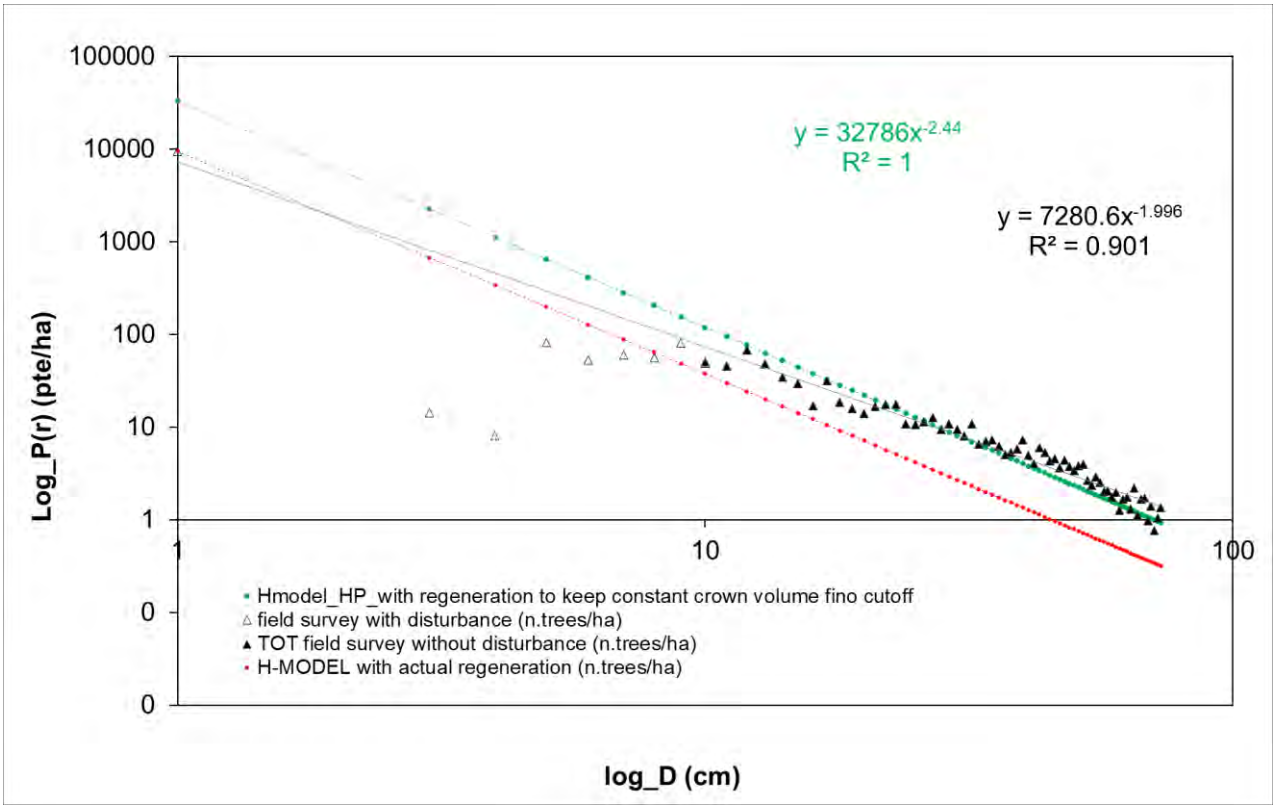

Figure 3. Comparison of the tree distribution in diametric classes at the field survey (black), according to the H-model with regeneration number at the survey time (red) and the H-model distribution with conservative crown volume (green). Montes Forest 2023.

Silvicultural actions using the H-Model Conservative Crown volume - HMCC

These data can be useful in several ways. Based on the current abundance of trees D<1 cm, which is about 9440 individuals per hectare, we made a simulation as shown in Figure 4. Here, the number of trees belonging

to the small diameter group has to be implemented, while a large part of the forest cover would need extensive thinning to ensure the forest structure balance over time A summary per D class of 1 cm is reported as follows:

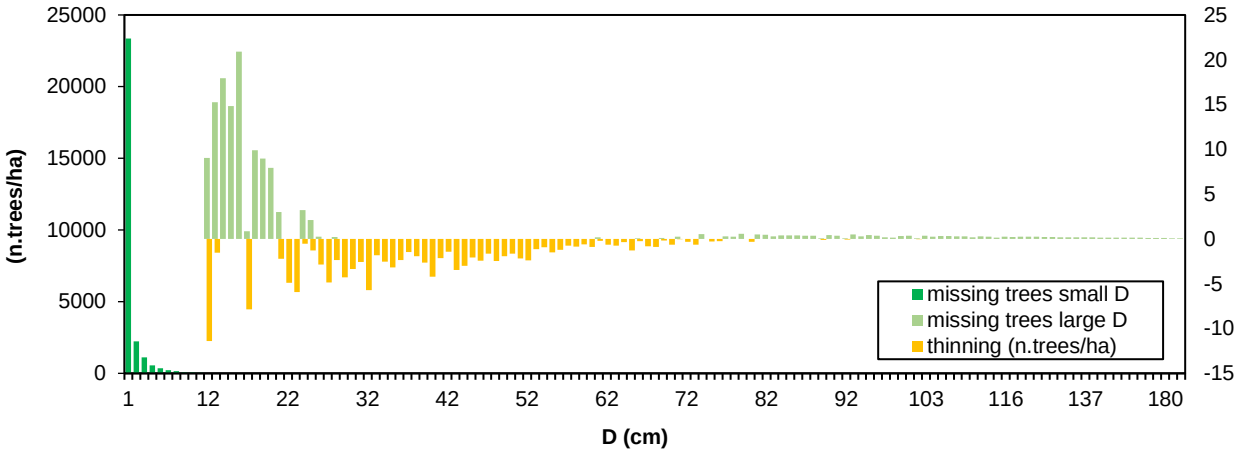

Figure 4. Silvicultural action based on H-model Conservative Vcro y = 32786x-2.4, number of trees per class (1cm bin size).

In general, no intervention is required for trees with D>70 cm. The most consistent focus should be on ensuring natural regeneration, whether the manager intends to provide a sound basis for guiding the forest towards a self-sustaining natural evolution. However, since the interpretation of the 1 cm class as a target may not be practical for forest management, we created an alternative classification that combines the 4 diametric classes based on DREAM silvicultural actions (Figure 5) + 2, one to include the small regeneration D<10 cm and one to include the extremely large trees.

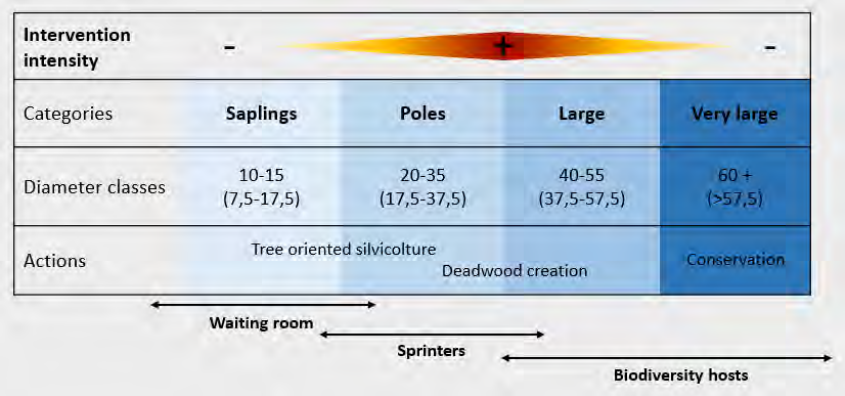

Figure 5. Silvicultural action by diametric class according to DREAM. The intervention model for the IB, takes the form of a per-tree-foot or small-group intervention, through which the stand is aimed at moving toward high-natural conditions. Silvicultural choices are made on 4 groups of diametric classes.

The cumulative number of trees per each silvicultural class described above is summarized in Figure 6. In Regeneration, Saplings and Poles classes the number of missing trees is large compared to the HMCC.

The cumulative estimated crown volume (ECV) per each diametric class (referable to a cylinder as previously described) is multiplied by the number of trees detected in the field survey and by the number of trees

estimated by the HMCC (Figure 7). The category "super large" for the H-Model remains empty because the H-Model projection ends at D=73cm.

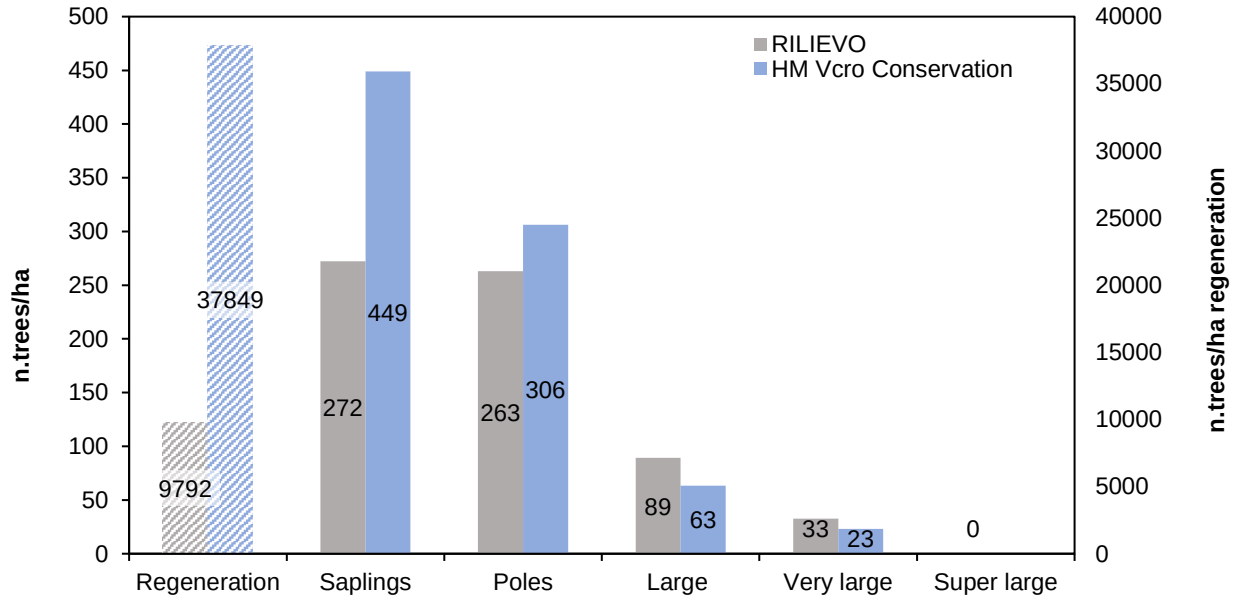

Figure 6. Number of trees per hectare per silvicultural class in the survey and in the HMCC.

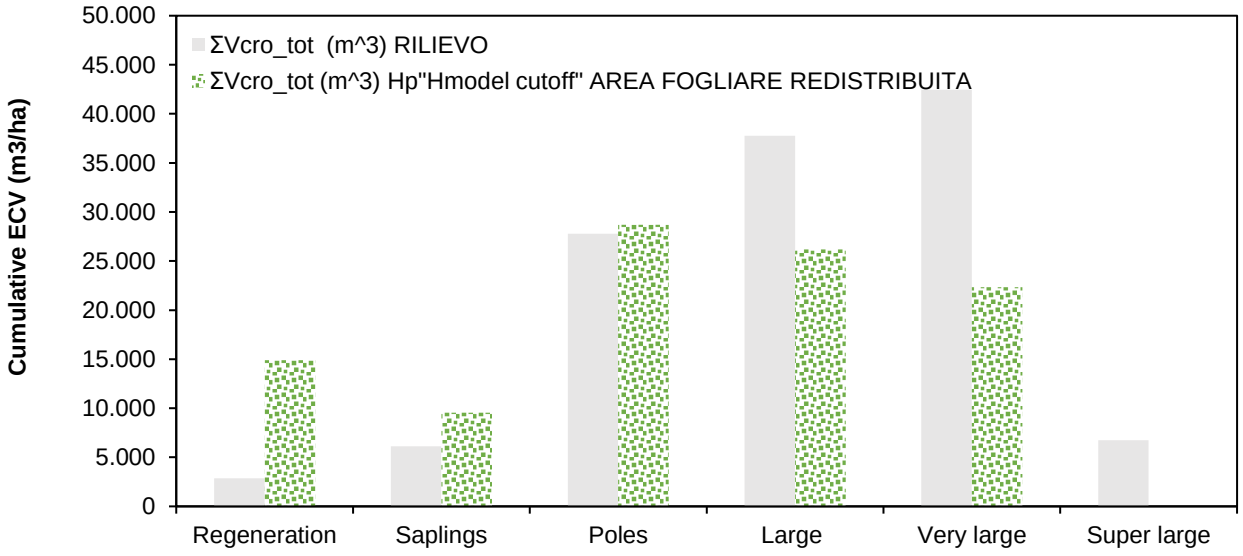

Figure 7. Estimated crown volume per hectare per silvicultural class in the survey and in the HMCC.

As we can see Large and Very Large trees are those which have a cumulative crown volume that is much larger in the field survey compared to the projection. The missing crown volume is respectively:

Classes	Regeneration	Saplings	Poles	Large	Very large	Super large
Range (cm)	0-10	10-15	15-35	35-55	55-100	100+
Missing crown volume (m^3)	-12 041	-3 445	-886	11 570	20 100	6 751
Missing tree n./ha	-28 057	-177	-43	26	10	6

Wood biomass estimation

The stem volume was calculated with the equation extrapolated by Prof. Lucio Susmel from field sampling and allometric studies on the very same site for the holm-oak. The wood mass here is measured in kg of dry weight with the equation $y=0.1198*x^{2.435}$. The outcome was also compared with the second order polynomial equation proposed by Tabacchi et. al on the same species. From the comparison resulted that there is an $R^2 = 0.9956$ and $y = 1.0439x-721.54$. When the single tree weight measured with the two methods is multiplied by the actual n. of trees per class estimated by the H-model, we derived a picture that show an overall difference of wood weight per hectare (stem and large branches D>3cm). When we used the Susmel method that did not give negative values for small classes, thus we decided to use this method as more precise for small classes.

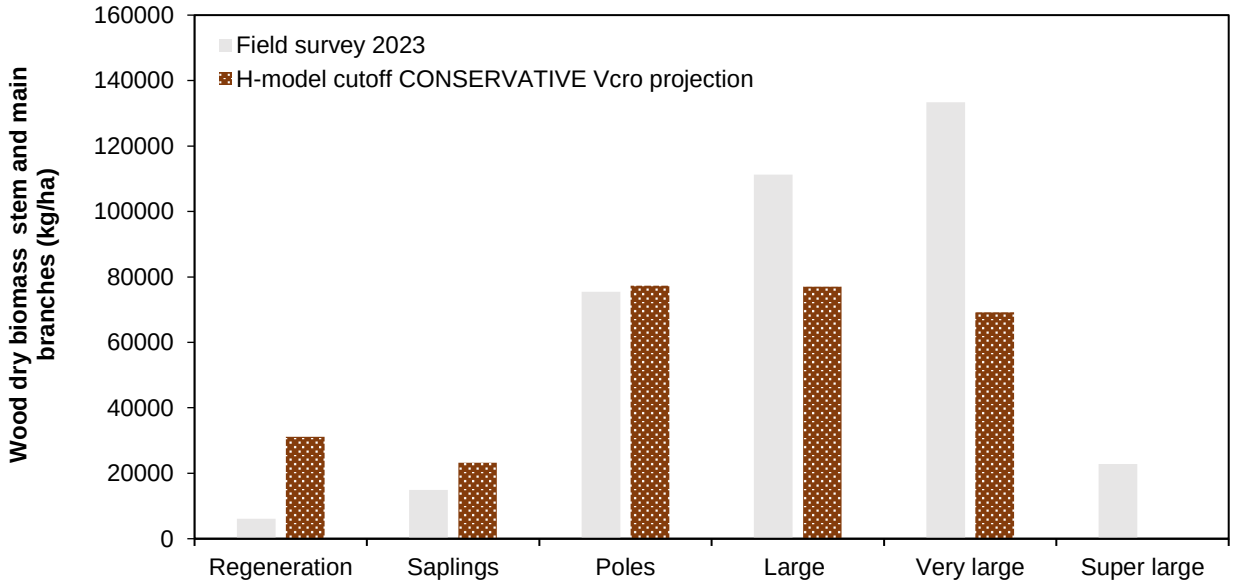

Figure 8. Estimated wood dry biomass per hectare per silvicultural class in the survey and in the HMCC.

The Removal of trees in classes “Large” and “Very Large” (40 trees/ha) would produce 98 350 kg/ha of biomass which on their turn would leave space for the development of Regeneration and Saplings, and in a moderated proportion to Poles.

Class (cm range)	*Susmel equation (kg/ha)*		*Diff.*
	Field survey 2023	***HMCC***	
	cumulated mass	***cumulated mass***	
1-10_Regeneration	6073	31185	-25113
10-15_Saplings	14921	23272	-8351
15-35_Poles	75453	77304	-1850
35-55_Large	111254	77073	34181
55-100_Very large	133412	69243	64169
100+_Super large	22878		22878
Overall TOTAL	**363991**	**278077**	**85913**

On the Island of Biodiversity "IB" - areas in transition

Tree species partitioning

The species share is much more simplified in these areas where in all layers over 90% of the vegetation is composed by helm oak. Notably in the regeneration transect we found a 10% presence of *Pinus pinaster* and 4% of *Erica arborea.*

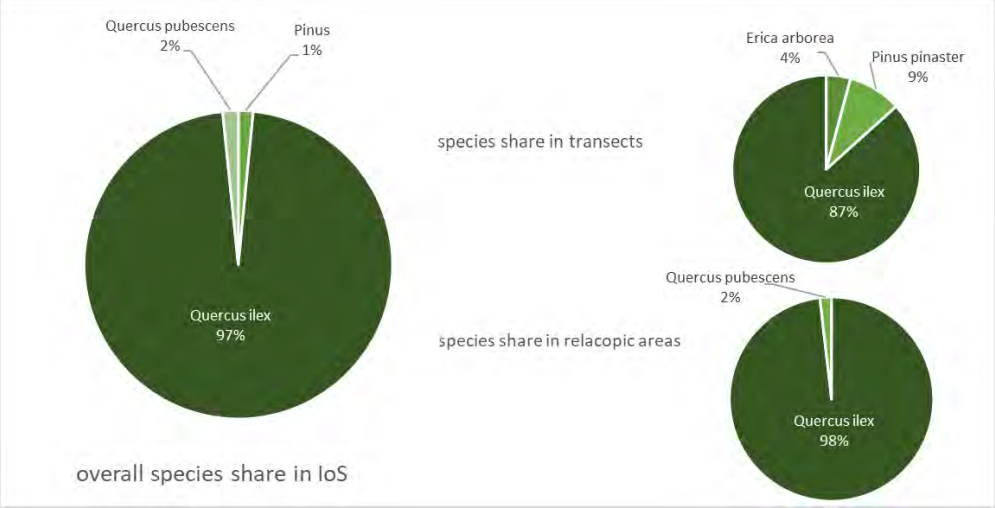

Figure 9. Species share in IB 2023.

H-model comparison with field survey

A brief summary on data based on the 20 sample areas on IB. The mean diameter in these areas is 37.46 cm and reaches a maximum of 75 cm. The cumulative ECV at the time of the field survey was 110 182 m^3/ha. We use this as a reference of crown volume that can metabolically support the community. The value is lower than the old growth area because most of IB are on slopes with more shallow soil. Thus, by keeping constant the crown volume we derived the number of trees in the regeneration layer as the intercept to apply the H-Model and preserve the crown volume that there is now. The diametric distribution from field survey and from the H-Model application is the following:

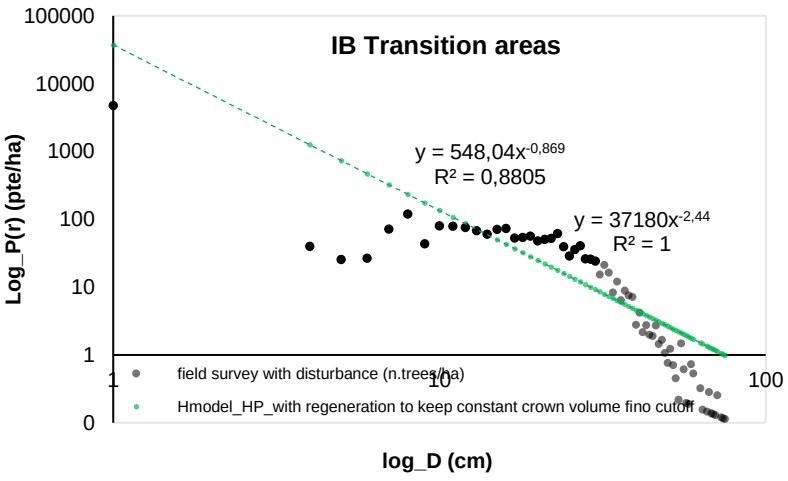

Figure 10. Comparison between field survey and HMCC dimetric distribution in IB 2023.

Predicted distribution with conservative crown volume approach

Silvicultural actions using the H-Model Conservative Crown volume - HMCC

After 30 cm in diameter the number of plants is quickly dropping after a plateau which ranges between 9 and 30 cm. Also, in this case we present the the number of trees/ha per each silvicultural class according to the field survey and to the HMCC projection both in 1cm classes and summarized in the main silvicultural classes:

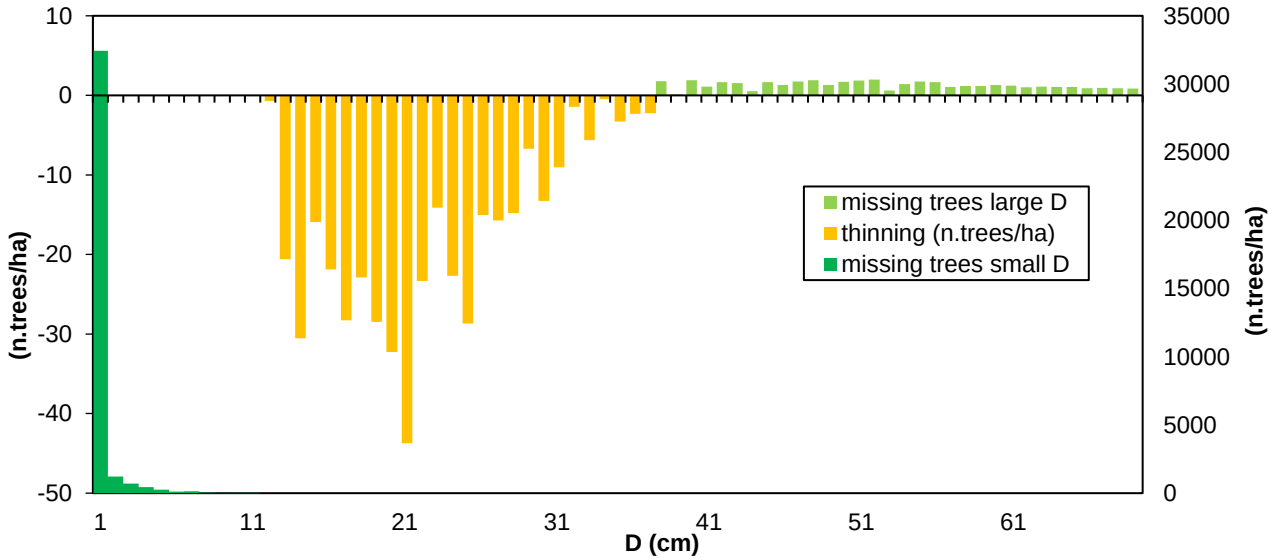

Figure 11. Silvicultural action based on H-model Conservative Vcro y = 32786x-2.4, number of trees per class (1cm bin size) in IB 2023.

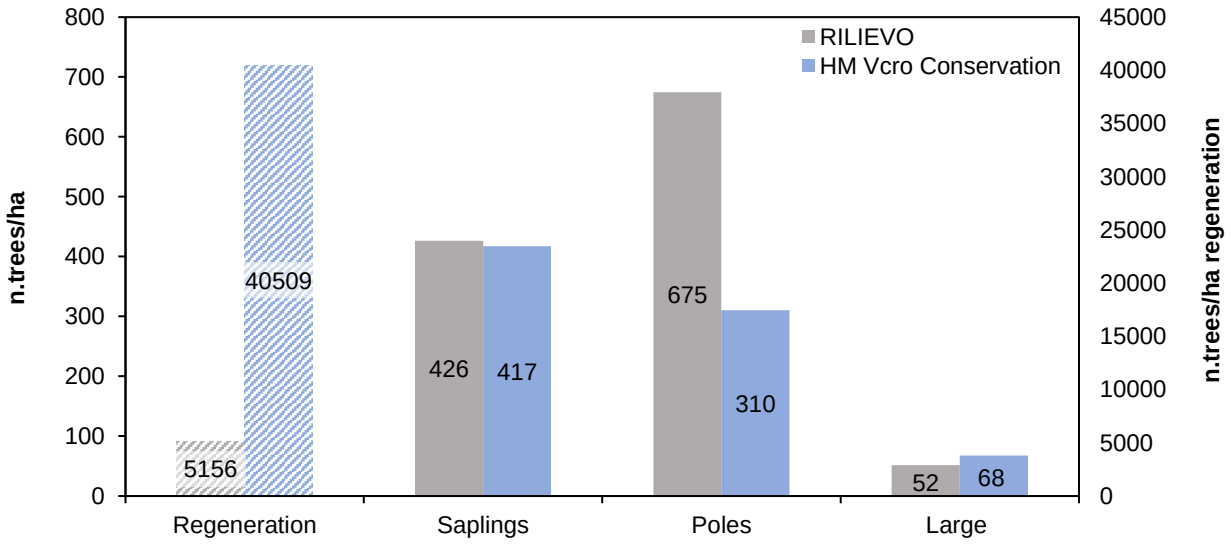

Figure 12. Number of trees per hectare per silvicultural class in the survey and in the HMCC in IB 2023.

It is clear that the "Poles" class is the one with higher exceeding individuals in the field compared to the H-Model (346 trees/ha), while the "Regeneration" class is the one that misses the most (-35 345 trees/ha). The classes "Saplings" and "Large" are those in which the present and the H-Model distribution are the most in equilibrium. In terms of cumulated ECV distribution per class we notice that of the ECV excess is present in the "Poles" class that is indeed between 15 and 35 cm.

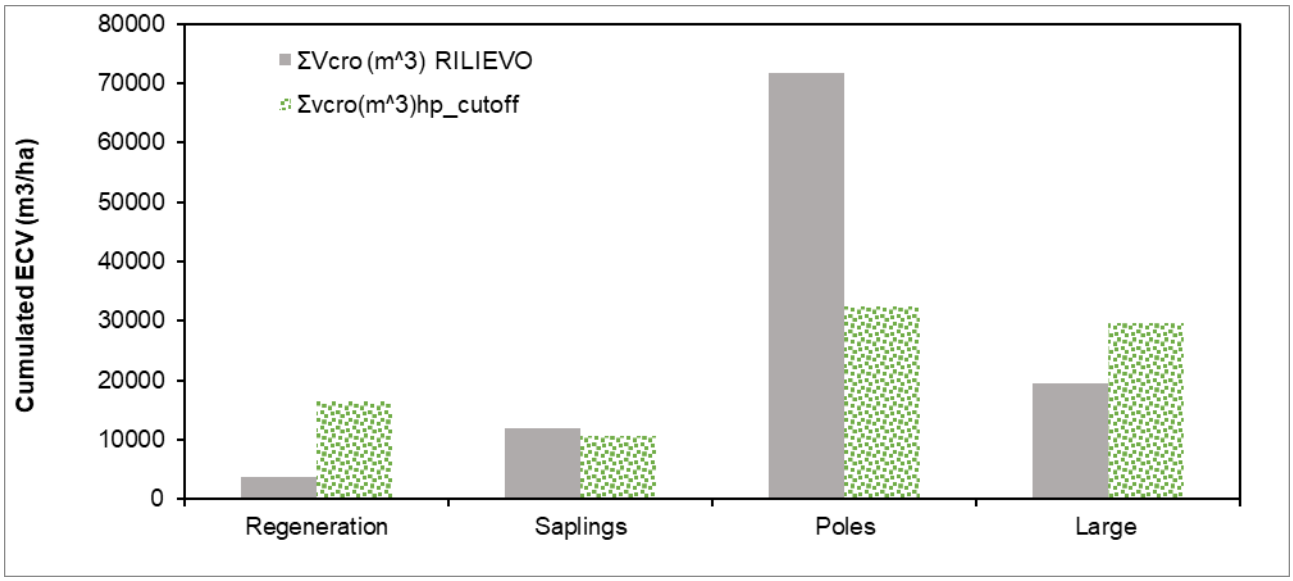

Figure 13. Estimated crown volume per hectare per silvicultural class in the survey and in the HMCC.

The silvicultural action shall be taken mainly in reducing the crown volume in the "Poles" class by the reduction on tree n. in this class to open clearings for new regeneration that is now only 12% of the amount suggested by the H-Model to respect the equilibrium.

Wood biomass estimation

The Wood biomass corresponding the excess of individuals in the "Saplings" and "Poles" is 110 000 kg/ha which removal should leave space to Regeneration and the enlargement of large trees.

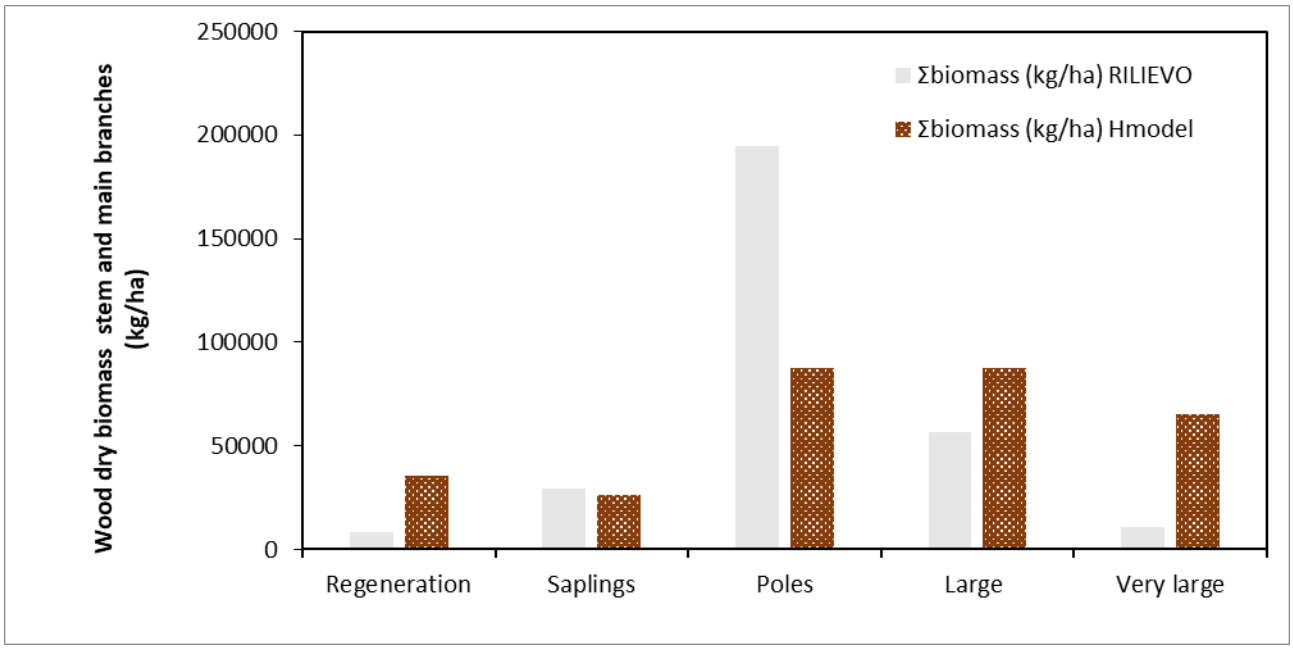

Figure 14. Estimated wood dry biomass per hectare per silvicultural class in the survey and in the HMCC.