



LIFE4FIR – Project LIFE18 NAT/IT/000164

“Decisive in situ and ex situ conservation strategies to secure the critically endangered Sicilian fir, *Abies nebrodensis*”

Report:

‘Distribution of natural regeneration of exotic Abies (including a map) C2.3’



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1. Introduction

This report is dedicated to the activity conducted in the C2.3 sub-action aimed at the identification and characterization of populations of non-native fir trees, planted in the course of reforestation activities carried out by the former Azienda Regionale Foreste Demaniali in previous decades, to evaluate their structural characteristics and dendrometric parameters, to assess their vegetative and phytosanitary state, as well as the evolutionary dynamics in course. This activity was conducted by the Unipa-Saaf and IPSP-CNR staff between June and September 2021.

During the previous project LIFE00 NAT/IT/007228 (2001-2005), approximately 1000 trees of non-native firs were removed or used as rootstocks for grafted scions of *Abies nebrodensis*. Due to the presence in the Madonie Regional Park territory of areas reforested 40 years ago with exotic fir species, to ensure the maintenance of the genetic purity of *A. nebrodensis* in the future is essential to detect and quickly remove the remaining adult trees and the developing plants of the natural regeneration of those alien firs.

Surveys conducted before the start of the Life4fir project revealed the presence of non-native *Abies* species in plantations, *A. cephalonica* and *A. alba* seedlings, young and pollinating fir trees in Piano Battaglia and loc. Comunello and in other sites of the Madonie range. This action is aimed at the identification and removal of non-native firs escaped to the previous interventions. Before starting the activity in the field, the measures carried out in this regard during the previous LIFE2000 NAT/IT/7228 Project ‘Conservation in situ and ex situ of *Abies nebrodensis* (Lojac.) Mattei’ were taken into consideration.

After a series of surveys in the territory of the Madonie Regional Park, particular attention was given to the plantations located in the vicinity of the *A. nebrodensis* natural population within an area of 15 km radius (Fig. 1). The largest plantations of alien firs (*A. alba* and *A. cephalonica*) are located in loc. Margi (municipality Castellana Sicula), loc. Comunello (municipality Isnello), loc. Savoichella / Pizzo di Corvo (municipality Petralia Soprana), municipal pinewood of Petralia Sottana and loc Fegotti (municipality Geraci Siculo).

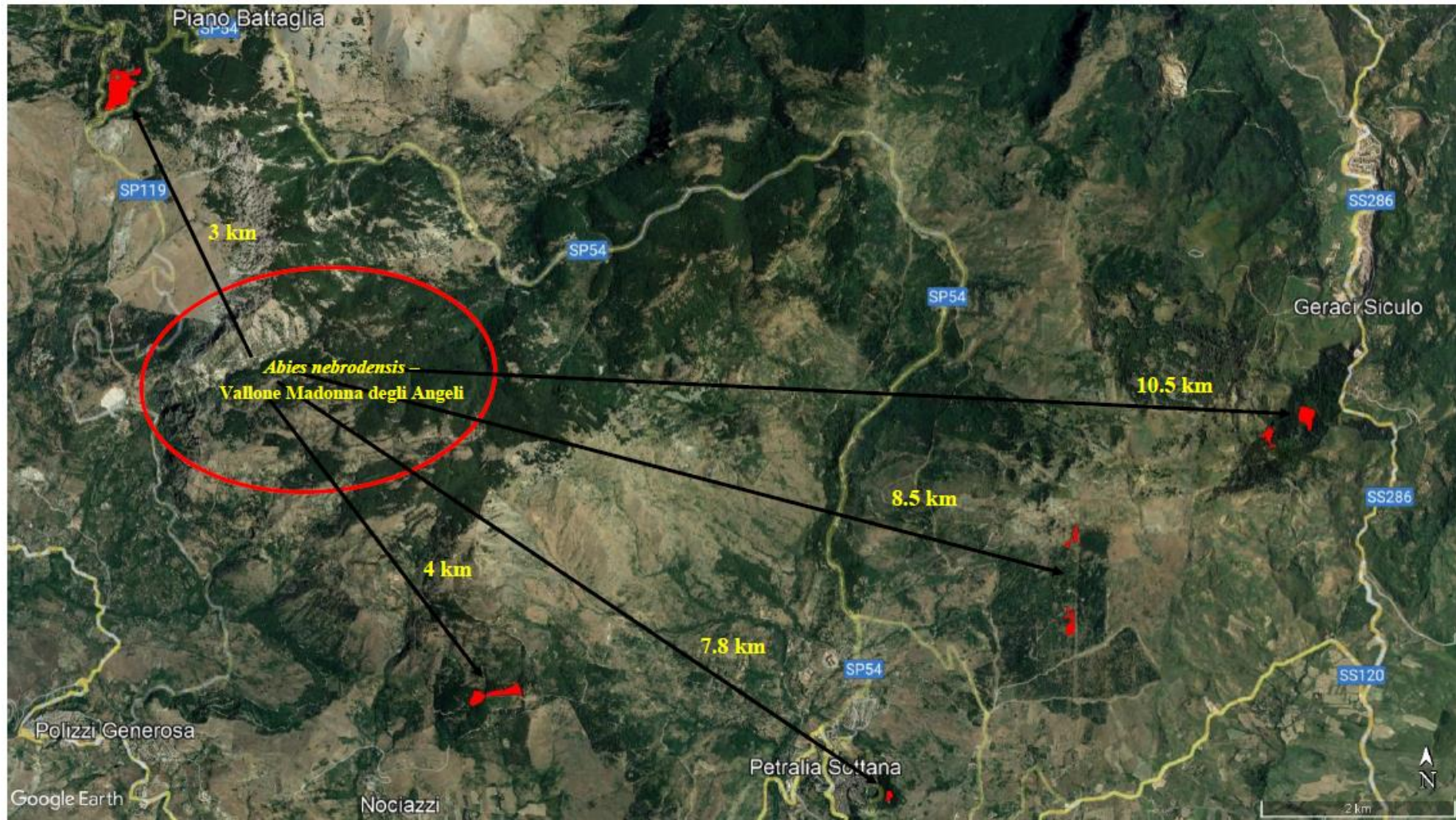


Fig. 1 Satellite map showing the linear distance between the non-native fir plantations surveyed and the natural population of *A. nebrodensis* located in the Madonna degli Angeli Valley.

2. Procedures

The characterization of the alien fir stands was carried out according to the following main phases:

- General approach to the work and definition of the relevant criteria;
- General survey of the area of interest;
- Development of a specific project using GIS;
- Preliminary identification of the main populations of exotic fir trees in the area;
- Delimitation and mapping of the identified populations, with the aid of GPS technology (Figure 1);
- Punctual recognition of individual populations and collection of general descriptive data;
- Identification and localization of the sample plots for each single stand;
- Execution of dendrometric surveys;
- Execution of surveys on the natural regeneration of alien fir trees;
- Dendrometric data processing;
- Final development of the G.I.S. and drafting of the thematic map.

2.1 Dendrometric survey

Dendrometric survey represented the most important phase of the work of characterization of the alien fir plantations as it allowed to obtain all the quantitative and qualitative information needed. The dendrometric survey had three objectives: 1) evaluate the state and environmental value of the plantation; 2) collect data for the calculation of the exploitable wood masses; 3) evaluate the growth rate of the forest. A simplified survey was carried out, since the main objective was to estimate the total number of specimens belonging to alien species of the genus *Abies* growing in the areas adjacent to that of the native *A. nebrodensis*. However, the large amount of dendrometric data collected, will eventually allow to estimate other important parameters such as the growing stock and the yield obtainable following the thinning or cutting of the alien fir trees; or silvicultural interventions on the indigenous species (beech, maple, holm oak, etc.) in case of mixed stands. The dendrometric surveys were carried out using circular sample plots, each having a radius of 15 m (706,86 m²). The most important phase of the work was the placing of the sample plots representing as much as possible the average characteristics of the populations of alien fir trees. The sample plots were chosen following a subjective criterion. In all the sample plots, the total inventory of trees was performed, starting from a threshold of 4 cm in diameter and the

measurement of a suitable number of dendrometric heights. More precisely, after placing a pole in the point chosen as the center of a sample plot, a 15 m distance was taken with a measuring tape in the four cardinal directions, identifying the four quadrants (Figure 2). Using the Vertex IV device, all the trees outside the 15 m radius were identified and marked with a chalk starting from the north and proceeding clockwise. After all trees falling within the sample plot were identified, the photographic documentation was created, the site characteristics form was filled in and then the dendrometric and structural parameters were recorded. Once the identification number and the species of the trees was reported for each quadrant (along with the number of stumps and suckers, in the case of mixed coppiced stands), the diameter at breast height (D1.30) was measured with a caliper, considering a threshold of 4 cm. In addition, for each sample plot, using the Vertex IV device, 30 heights associated to different diameter classes were measured.

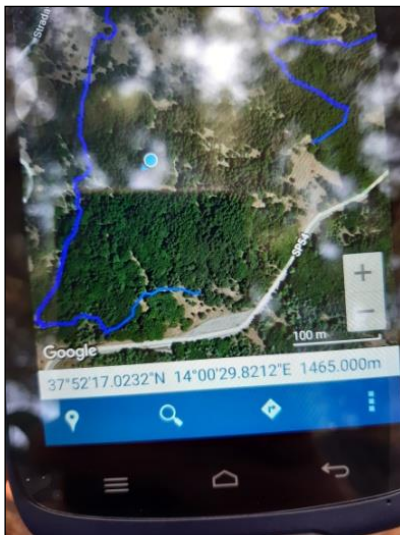


Fig. 1. Delimitation of plantations using a GPS device



Fig. 2. Dendrometric survey in pure *A. cephalonica* plantations at loc. Comunello (Isnello)

The data related to diameters and heights recorded for sample plot allowed the processing of the respective hypsometric curves, which graphically express the variation in the height of the trees in relation to their diameter. For the analytical equalization of the hypsometric curves the following semilogarithmic function was used:

$$y = a + b \ln x$$

The previous equation expresses the height, y , as a function of the diameter, x , even in the case of uneven aged and multi-layered populations.

After distributing the trees in diameter classes from 4 to 120 cm (class width of 2 cm for $4 < d < 50$ cm and class width of 10 cm for $51 < d < 120$ cm), the absolute frequencies, relative frequencies and percentage frequencies were calculated. The same was done for the heights, which ranged from 2 and 30 m (with class width equal to 2 m).

For all sample plots, the following parameters were calculated:

1) frequency per hectare, with the following equation

$$N_p / ha = (N_t / S_t) 10,000$$

where: N_p / ha = total number of plants per hectare; N_t = number of coppice shoot / plants within the sample plot; S_t = surface of the sample plot (m^2)

2) basal area per hectare (G / ha), given by the sum of the cross sections at 1.30 m referred to the hectare:

$$G/ha = \left(\sum_{i=1}^N d_i^2 \pi / 4 S_t \right) 10000$$

where, G / ha = basal area per hectare; d_i = diameter of the i -th living tree; N = number of plants in the sample plot; S_t = surface of the sample plot (m^2)

3) mean basal area (gm), obtained as the sum of the basal areas referred to N_t

$$gm = \left(\sum_{i=1}^N d_i^2 \pi / 4 \right) / N_t \text{ (cm}^2\text{)}$$

4) diameter of mean basal area (dm), which corresponds to the diameter of the tree with medium basal area and is calculated with the relation

$$Dm = \sqrt{\frac{4 gm}{\pi}} \text{ (cm)}$$

5) average height (Hm), corresponding to the height of the tree with of mean basal area resulting in the hypsometric curve or calculated as the arithmetic average of the heights of the plants with a diameter close to dm ;

6) average height (H_L), (calculated with Lorey's formula) defined as the average weighted of the heights with the corresponding basal area weight

$$H_L = \frac{\sum \pi/4 d_i^2 h_i}{\sum \pi/4 d_i^2}$$

7) dominant height (H_d) calculated as the average of the heights of the 100 largest plants per hectare;

8) dendrometric height of each tree in the sample plot, obtained from the hypsometric curve in relation to the D.

For the sample plots falling into mixed stands, in which alien fir trees are mixed with indigenous broadleaved trees, the following parameters were also obtained:

9) Number. of stumps / ha;

10) Number of seed plants / ha;

11) Number of coppice shoot / ha;

Furthermore, to study the evolutionary dynamics occurring in each population, specific surveys were eventually carried out on the natural regeneration of *A. alba* and *A. cephalonica*. The survey on the natural regeneration of the alien fir was carried out by means of numerous rectangular 2 x 20 m transects, covering an area of 40 m² (Figure 3 and 4).



Fig. 3 and 4. Survey on the natural regeneration in a *A. cephalonica* plantation

3. Results

During the previous project LIFE2000NAT / IT / 7228 “Conservation in situ and ex situ of *A. nebrodensis* (Lojac.) Mattei”, which took place from 2002 to 2005, a first survey on the Madonie territory aimed at identifying trees of non-native fir species was carried out.

At the end of this survey, no. 80 single trees of Greek fir or silver fir and 62 trees part of small groups (2-10 plants), located in private or public gardens of the Madonie villages were identified. Some populations of variable size were also identified in different areas of the Madonie territory as result of previous reforestation activities.

As part of the activity here reported, inspections were first carried out in the public and private gardens where non-native fir trees were reported. Then, an intensive activity was addressed to the identification and characterization of plantations of *A. cephalonica* and *A. alba* located in forested areas of the Madonie territory.

For each of the main populations of alien fir trees identified, surveys and analysis were carried out to characterize them in terms of dendrometric, structural and ecological aspects. The following paragraphs report the main results and the dendrometric data obtained.

Ten main plantations (based on their width) of alien fir trees (*A. alba* and *A. cephalonica*) have been identified, located within 15 km from the natural population of *A. nebrodensis*. These plantations are located in loc. Margi (municipality Castellana Sicula), loc. Comunello (municipality Isnello), loc. Savochella / Pizzo di Corvo (municipality Petralia Soprana), Pinewood of Petralia Sottana and loc. Fegotti (municipality Geraci Siculo).

Among the populations identified, the most important, both in terms of width (7.5 hectares) and vicinity to the indigenous area of *A. nebrodensis*, is that of loc. Comunello, falling within the municipality of Isnello. Based on the canopy, density and above all the specific purity (mixed stands with broadleaved trees or pure Greek or white fir forest), the population of loc. Comunello was divided into four sub-populations, where as many as 4 sample plots were arranged for each of them to conduct a representative survey (Figure. 5).

The second population, both due to its width and to the number of trees represented, is that of loc. Fegotti, in the territory of Geraci Siculo. For the same reasons previously described, two sub-populations were identified for a proper survey (Figure. 6).



Fig. 5. Satellite map of the plantation of *A. cephalonica* in loc. Comunello (Isnello) reporting the four sub-populations.



Fig. 6 – Satellite map of the plantation in loc. Fegotti (Geraci Siculo) reporting the two sub-populations reported.



Figure 7: Images of some surveyed populations of non-native firs (Ads = sample plot)

According to the objective of this survey, the characterization of the targeted populations was based on the following dendrometric parameters: area in hectares of the stand (ha); frequency (N_p / ha) of trees of all species growing in the population; number (N), frequency (N_p / ha) and mean diameter (cm) of the trees of *A. cephalonica* and *A. alba* for each of the ten populations identified. Results obtained for the populations surveyed are summarized in the following table.

Plantation locality	Area. (ha)	Freq. tot. (N/ha)	Freq. Greek fir (N/ha)	d _m Greek fir (cm)	Freq. Silver fir (N/ha)	d _m Silver fir (cm)	Freq. Other species (N/ha)	N. Greek fir	N. Silver fir
<i>Comunello AdS 1</i>	2.37	1896	509	24.7	255	20.6	1132	1206	604
<i>Comunello AdS 2</i>	2.97	877	863	29.5	14	5.0	0	2563	42
<i>Comunello AdS 3</i>	1.21	1641	170	35.1	226	32.3	1245	206	273
<i>Comunello AdS 4</i>	1.0	2674	212	25.5	43	10.1	2419	212	43
<i>Savochella (area 1)</i>	1.73	269	85	15.2	-	-	184	147	-
<i>Savochella (area 2)</i>	0.86	1358	184	26.1	382	23.5	792	158	328
<i>Margi</i>	4.43	453	42	35.5	-	-	411	186	-
<i>Geraci S. Sp 1</i>	1.26	2221	707	24.2	28	25.1	1486	890	36
<i>Geraci S. Sp 2</i>	2.87	920	481	28.6	-	-	439	1380	-
<i>Pinewood Petralia Sottana</i>	0.47	1019	85	33.1	325	31.4	609	40	153
Tot	19.17							6988	1479

Tab. 1 – Main traits of the surveyed plantations of non-native firs

From the data reported in Tab. 1, the total area covered by plantations of non-native fir trees in the forest was 20 hectares and that the current total consistency is 6,988 trees of Greek fir and 1479 of silver fir (with a trunk diameter higher or equal 4 cm at breast height).

The mean diameter was different among the plantations of Greek fir, ranging between 15.2 and 35.5 cm; while, for the silver fir, it ranged between 5.0 and 32.3 cm. In relation to the presence of broadleaves, only the sample plot no. 2 in the Comunello stand was pure (Greek fir), while the others were mixed with broadleaved trees. In the sample plot no. 4 in Comunello stand, the frequency of broadleaves was prevalent compared to fir trees. As regards the populations of loc. Comunello, the total area was 7.55 hectares; the trees of Greek fir and silver fir estimated were respectively 4,187 (the total value of the ten stands is 6988) and 962 (the total value of the ten stands is 1479).

As regards the natural regeneration of exotic fir trees, in all the populations identified, specific surveys were carried out along rectangular transects (oriented to the North) of 2 x 20 m on each side (40 m²). The following parameters were recorded: number (N) of 1-year-old seedlings; number of plants older than 1-year for each predetermined height class (class width: 3 cm). To obtain accurate estimates, different ecological conditions were sampled: marginal areas of the forest, areas inside the forest and clearing areas.

With reference to the population of loc. Comunello, to provide an indicative summary of the evolutionary dynamics of the natural regeneration of the alien fir trees in course, the mean values per hectare of the seedlings and young plants is reported in Tab. 2.

<i>Loc. Comunello</i>	Seedlings < 1 year old (N/ha)	Seedlings h > 3 cm (N/ha)	Plantlets h > 6 cm (N/ha)	Plantlets h > 9 cm (N/ha)	Plantlets h > 12 cm (N/ha)	Plantlets h > 15 cm (N/ha)	Plantlets h > 18 cm (N/ha)	Plantlets h > 21 cm (N/ha)	Plantlets h > 24 cm (N/ha)
<i>Forest edge</i>	153,750	15,000	16,500	7,250	4,250	750	-	-	-
<i>Inner plantation</i>	2,814,000	30,000	66,000	10,500	42,000	24,500	4,000	1,000	1,000
<i>Cleaning</i>	651,250	55,000	104,750	11,750	6,750	1,500	500	-	-
Mean	1,206,333	33,333	62,417	9,833	17,667	8,917	1,500	333	333

Tab. 2 – Dati rinnovazione naturale di abeti alieni del popolamento di C.da Comunello.

The data obtained showed that the plantation of *A. cephalonica* of loc. Comunello has reached maturity, and based on the abundance of the natural regeneration, this area seems to provide very good conditions to the growth and reproduction of the species. The average number of seedlings born in April 2021 (therefore with an age <1 year) is extremely high: over one million per hectare. Furthermore, in the areas where crashes or openings of the canopy occurred to due to various causes, a massive natural regeneration was detected, with seedlings that were 7-15 years-old and saplings which reached even 1 meter in height.

A similar situation reported for loc. Comunello was found in the plantation of loc. Fegotti Geraci S. (sample plot no. 1). The mean values referred to natural regeneration are reported in the Table 3.

<i>Fegotti Ads 1</i>	Seedlings < 1 year old (N/ha)	Seedlings h > 3 cm (N/ha)	Plantlets h > 6 cm (N/ha)	Plantlets h > 9 cm (N/ha)	Plantlets h > 12 cm (N/ha)	Plantlets h > 15 cm (N/ha)	Plantlets h > 18 cm (N/ha)	Plantlets h > 21 cm (N/ha)	Plantlets h > 24 cm (N/ha)
Mean	896,456	27,056	47,116	6,233	14,231	6,612	1,150	172	295

Tab. 3 – Dati rinnovazione naturale di abeti alieni del popolamento di C.da Fegotti – Geraci S. Ads 1.

In the other plantations, due to less favourable ecological conditions, the natural regeneration of alien fir trees is fortunately absent, except for the loc. Fegotti - Geraci Siculo. sample plot no.2, in which, due to the thick ground cover, natural regeneration was present but not very widespread.

Mean values are reported in Tab. 4.

<i>Fegotti Ads 2</i>	Seedlings < 1 year old (N/ha)	Seedlings h > 3 cm (N/ha)	Plantlets h > 6 cm (N/ha)	Plantlets h > 9 cm (N/ha)	Plantlets h > 12 cm (N/ha)	Plantlets h > 15 cm (N/ha)	Plantlets h > 18 cm (N/ha)	Plantlets h > 21 cm (N/ha)	Plantlets h > 24 cm (N/ha)
Media	85,125	6,002	6,321	1,045	1,027	612	425	58	36

Tab. 4 – Dati rinnovazione naturale di abeti alieni del popolamento di C.da Fegotti – Geraci S. Ads 2.

4. Conclusions

The surveys carried out showed that *A. cephalonica* found very favorable conditions for growth and reproduction in the areas of introduction of the Madonie. Based on the data recorded, this species can be considered naturalized in Sicily. The proximity of the *A. cephalonica* plantations to the natural population of *A. nebrodensis* represents a real threat for the genetic integrity of the Madonie fir.

This is corroborated by the fact that the genetic analyzes recently carried out in the natural population of *A. nebrodensis* and in the local Piano Noce forest nursery on open-pollinated seedlings, have shown a significant rate of potential hybrids (about 40% of seedlings in the nursery).

The census of non-native fir trees carried out in this action C2.3, allowed to obtain a representative picture of the distribution and consistency of the plantations of non-native firs on the Madonie. The information collected are useful for planning the interventions aimed at the removal of such plantations, based on the actual threat they represent for the genetic integrity of *A. nebrodensis*, depending on vicinity, width and size reached by trees.

Based on the checklist of the alien vascular plant species reported in Italy by Galasso et al. (2018), *A. cephalonica* is an allochthonous species naturalized in Sardinia, Marche, Umbria and Friuli Venezia Giulia, while it is still sporadic in Abruzzo and Sicily. However, according to recently acquired data here showed, *A. cephalonica* can be considered as a naturalized allochthonous species for Sicily too.

Results of this investigation evidenced that the prompt removal of the adult trees and the natural regeneration of *A. cephalonica* introduced in the Madonie Regional Park is of primary importance to safeguard the genetic integrity of *A. nebrodensis*.

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