Article

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Forest ecosystems in the Monti Sicani Park (Sicily)

Abstract

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The authors analysed the forest ecosystems in the Monti Sicani Park (Sicily). In particular, the state of the natural and non-native forests in the Site of Community Interest (SCI ITA040005) - Monte Cammarata, Contrada Salaci, was evaluated in terms of distribution, evolution of forest dynamics and, silvicultural activities. The evolution of vegetation within two different forest plots are analysed and management strategies are proposed. The finding on Mount Cammarata of seedlings of *Fagus sylvatica* in the undergrowth of a conifer afforestation is noteworthy.

Key words: Reforested areas, *Cedrus atlantica*, Protected areas, Silvicultural management.

Introduction

Forests cover about 10% of the total area of the Mediterranean basin (FAO 2018). Mediterranean forest ecosystems express exceptional richness in terms of biodiversity. The most common threats that can make these ecosystems vulnerable and fragile are forest fires, overexploitation, deforestation, degradation and, incorrect silvicultural activities. These threats are accentuated today due to climate change, air pollution and, land use (Palahi & al. 2008).

In Sicily (southern Italy), even though many regional reserves and parks have been established, the interest for the Sicilian forest heritage has been mainly concretized in many reforestations. The incentive measures in the forestry sector introduced around 1970, have contributed to increase significantly the extension of the wooded areas which are, however, mainly constituted by non-native species (Domina & al. 2018b). Most of the reforested areas are in a worrying state of neglect resulting in obvious impacts on plant health, fire risk and, tree stability.

Among the different reforestations, those with *Cedrus atlantica* (Endl.) Carrière have had a better success, since the plants have found, in some environments of Sicily, ecological conditions more similar to those of their countries of origin. La Mela Veca & al. (2012) highlighted the excellent assertiveness of cedar trees and the possibility of

high wood production, equal to those found in the literature for plantations made in France (Courbet & al. 2018).

This study analyzes the state of the natural and non-native forests in the Site of Community Interest (SCI ITA040005) - Monte Cammarata, Contrada Salaci, evaluated in terms of distribution, evolution of forest dynamics and silvicultural activities.

Materials and Methods

Area of study

The Oriented Natural Reserve "Monte Cammarata" has been established with Council Decree n°86/44 (18 April 2000) by the Regional Department of Land and Environment (Sicily) on the base of the Regional Law n°98 (06 May 1981) on the protected areas, and it is registered to the n°1123 of the Official List of the Italian Protected Areas (Ministry of Ecological Transition). Subsequently, the Reserve (Council Decree n°281 19 December 2014), was named "Park of Monti Sicani".

It is a natural environment characterized by Mediterranean forest of evergreen and deciduous oaks and conifers. The park, which is included between the territories of the municipalities of Cammarata, San Giovanni Gemini and, Santo Stefano di Quisquina, occupies a vast area of ca. 2000 hectares, and is located at the northern end of the province of Agrigento dominated by the peaks of Mount Cammarata (1578 m), Mount Gemini (1392 m) and, Pizzo della Rondine (1254 m).

The climate type is Mesomediterranean-subhumid lower (Rivas Martinez 1995), with the exception of the highest areas of Mount Cammarata that are subjected to Supramediterranean-subhumid lower climate, with abundant rainfall and snowfall in winter (Bazan & al. 2015; Domina & al. 2018).

The vegetation is mainly represented by *Quercus ilex* L. subsp. *ilex, Q. pubescens* Willd. s. l., *Pinus halepensis* Mill., *P. nigra* J.F. Arnold subsp. *nigra*, *Hesperocyparis arizonica* (Greene) Bartel, and *Cedrus atlantica* (Endl.) Carrière. Along the valleys and in the most sheltered areas there are small groups of *Ostrya carpinifolia* Scop., *Ulmus canescens* Melville, *Populus nigra* L. and some few *Salix* species. Moreover, it is easy to recognize other sporadic trees such as *Acer campestre* L. and *Fraxinus ornus* L. Shrubs are mainly represented by *Phillyrea latifolia* L., *Pistacia terebinthus* L., *P. lentiscus* L., *Cistus salvifolius* L., *C. creticus* L., *Ruscus aculeatus* L., *Asparagus acutifolius* L., *Smilax aspera* L., and *Hedera helix* L.

Achantus mollis L., *Paeonia mascula* subsp. *russoi* (Biv.) Cullen & Heywood and several fern species, characterize the undergrowth.

Going up along the paved road that climbs up to the top of Mount Cammarata the landscape is characterized by *Euphorbia rigida* M. Bieb. and *Sorbus domestica* L.

The need to establish the park has arisen from the need to protect ca. 150 herbaceous species of which several are rare or endemic to Sicily such as: *Anthemis cupaniana* Tod. ex Nyman, *Senecio squalidus* subsp. *microglossus (*Guss.) Arcang., and *Bivonaea lutea* (Biv.) DC. For an exhaustive list of herbaceous species see the report of the excursion of the Italian Botanical Society in the area (Domina & al. 2015).

Methods

The state of the natural and non-native forests in the Site of Community Interest (SCI ITA040005) - Monte Cammarata, Contrada Salaci, was evaluated in terms of distribution, evolution of forest dynamics, and silvicultural activities. Moreover, a GIS-based forest category map was generated, characterizing the vegetation both through field surveys, and on the basis of the Map of Forest Types, and through the evaluation of the CTR (Regional Technical Map, Fig. 1). In order to identify the habitats included within the SCI, a geographical survey of the area under examination was carried out on a GIS basis. For cartographic elaborations, apart from the CTR (scale 1: 10,000), digital orthophotos were used with interpretation of vegetation coverage through "Bing" on GIS. In particular, the surfaces related to the different land use classes of the analysed territory have been reported. The classes are referred to the Corine Land Cover (2, 3 and, 4 levels) and are accompanied by the corresponding numerical codes. This has made it possible to categorize the different digitized surfaces and to attribute to each code a different colour representing a specific land use. Photo-interpretation, supported by several field surveys using the Map of Forest Types of the Territory made by La Mela Veca & al. (2005), allowed to stratify the categories, so as to distinguish natural from artificial forests.

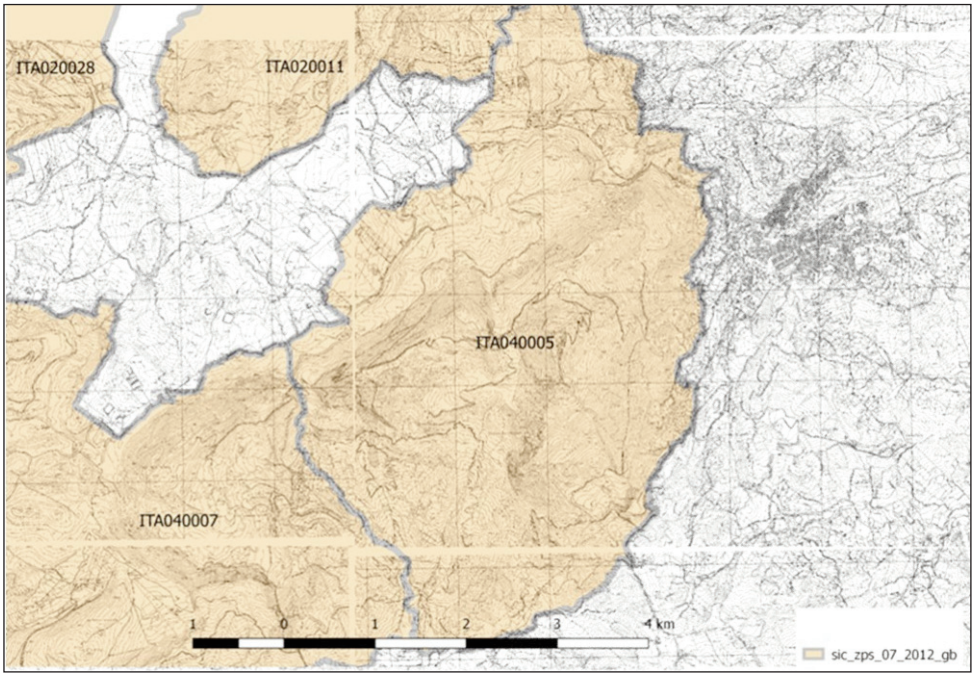

Fig. 1. Regional Technical Map (CTR) and delimitation of the Site of Community Interest (SCI ITA040005) - Monte Cammarata, Contrada Salaci.

Finally, two forest plots were bounded (Fig. 2) with the aim to analyse, over two years of observations, the evolution of trees, shrubs, and herbaceous species. The first plot, in locality Filici, located along the provincial road no. 24 "Cammarata - Santo Stefano di Quisquina", is characterized by silvicultural practices such as thinning carried out through clear cuts. The other plot is in locality Savochello and no silvicultural practice is carried out. The delimitation of these forest plots was carried out through the use of a measuring wheel, stakes and marking tape, allowing the identification of a variable number of plant species.

Within the forest plots we proceeded to the numbering of the plants and the analysis of their distribution in the different vegetation layers (tree, shrubby and, herbaceous). In addition, we also determined the degree of cover, calculated on the basis of the projection of the crown of the plants on the ground.

Silvicultural practices

The silvicultural practices are mainly carried out on the coniferal and distributed areas into two periods of the year: a) autumnal thinnings; b) spring thinnings.

Thinning carried out by means of flush cuts, was performed mainly to stimulate the natural regeneration of broadleaf trees and reduce the density of dense stands of conifers. Trees, once felled, are left "on the fall bed" flanked by a large pile of dry plant residues. The latter practice is not recommended as the huge amount of piled up plant material

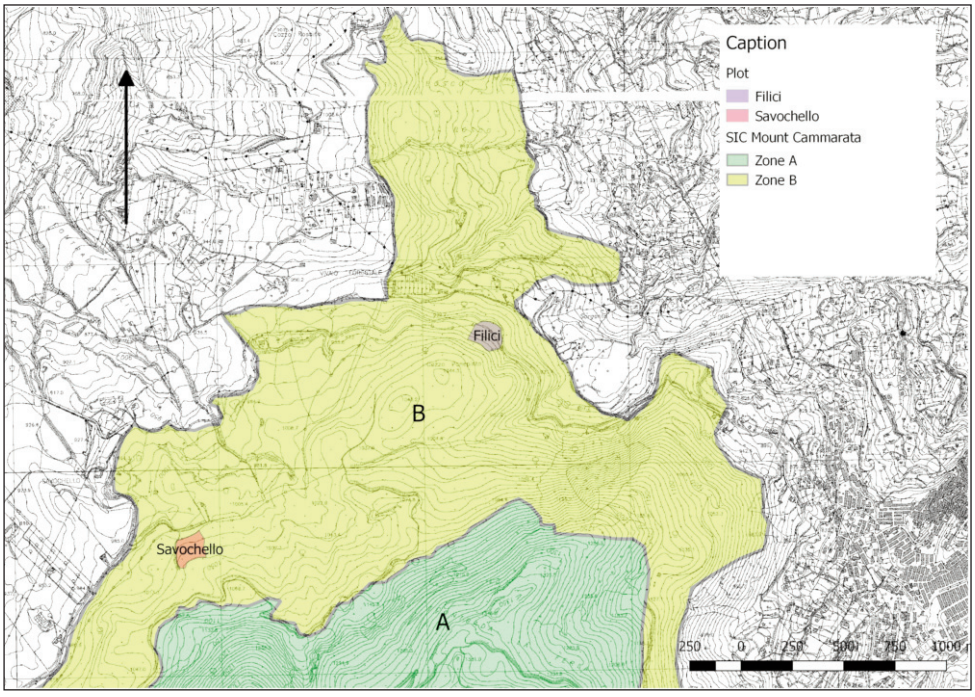

Fig. 2. Zone A and B of the Sicani Park and delimitation of analysed plots.

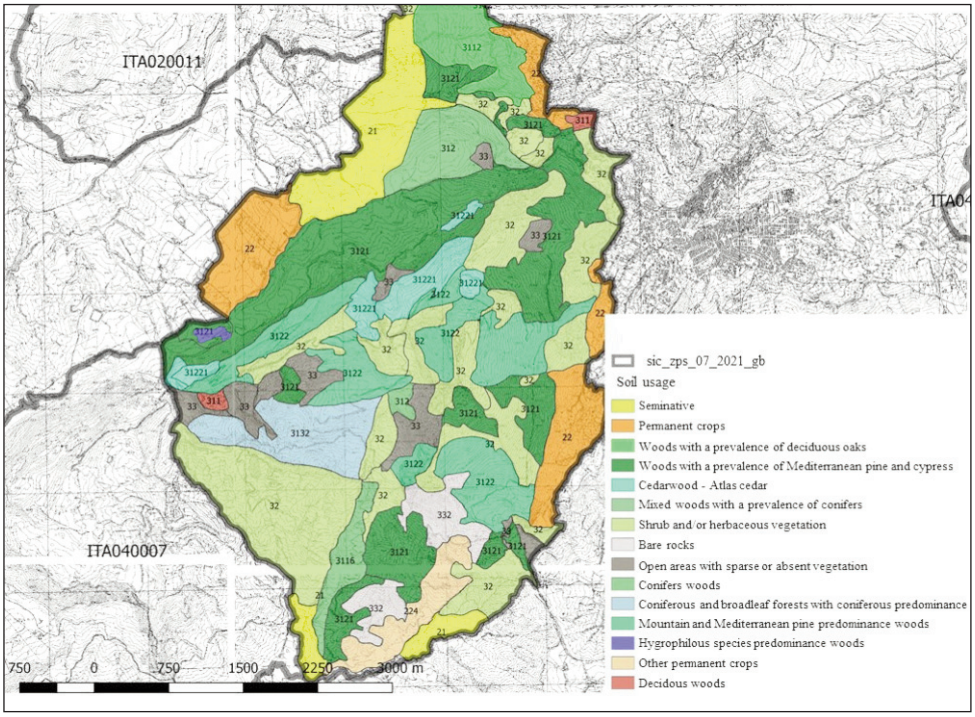

Fig. 3. Distribution map of forest types and land use in the Site of Community Interest (SCI ITA040005) - Monte Cammarata, Contrada Salaci.

increases the risk of fire within the study area. Between May and August, firebreaks are made in order to stop the advance of possible fires. Other practices consist of clearing main trails followed by cleaning firebreaks. In addition, forestry workers are assigned to the arrangement and cleaning of gutters and water-cutting transversals including the cleaning of slopes and removal of debris.

Evolution of vegetation in forest plots

The observation of the plant populations within the two forest plots, both located in "Zone B" of the Monti Sicani Park, has allowed, on the basis of the different silvicultural practices, to identify differences in evolutionary terms, in the entity and distribution of spontaneous processes of renaturalization of tree species but also the observation of shrubby and herbaceous indicator species. In forest plots with an excessive density of conifers, regeneration is scarce, as in the area of Savochello, where no thinning was carried out. On the other hand, the condition is different in areas, such as Filici, where thinning has been carried out.

The area of Filici, characterized by thinning on conifers, shows a strong renewal promoted by less competition and shading by the tall conifers introduced with reforestation (*Pinus halepensis*, *P. pinea*, *Cupressus sempervirens*, *Cedrus atlantica*) from seedlings

available in the nurseries of Sicily Region. The broadleaf trees are represented *Quercus ilex* L. subsp. *ilex*, *Q. pubescens* s. l., *Fraxinus ornus* mixed to *Prunus spinosa*, *Rosa canina*, *Cistus creticus*, *Ruscus aculeatus* and, sporadically, *Crataegus monogyna*.

The peculiarity and the most important characteristic in this area is that the thinning of conifers has led to a colonization not only of broadleaf trees but also to the natural renewal of *Hesperocyparis arizonica*, *Pinus halepensis* and, some seedlings of *Cedrus atlantica*. This is a very important aspect that allows to confirm how silvicultural practices, associated with a sustainable management based on the safeguarding of forestry coenoses, promote the development of a habitat in which there is a natural succession not only of the autochthonous oak species but also the growing, evolution and, development of conifers, which are extraneous to the natural context but which are able to establish themselves spontaneously. The presence of *Ampelodesmos mauritanicus* (Poir.) T. Durand is probably favoured in the settlement by natural reforestation.

In the Savochello plot the density is not very high and an association of different species of conifers, such as cypresses, pines and cedars can be observed. Significant natural regeneration was observed in the area where thinning is being done. The most represented species are *Quercus ilex* subsp. *ilex* and *Q. pubescens* s. l. in variable numbers according to the ecological features of the forest plot and the percentage of coverage. In these areas, besides the species mentioned above, the presence of *Acer campestre*, *Ostrya carpinifolia,* and *Fraxinus ornus* can also be observed together with *Pinus halepensis*, *P. pinea, Quercus pubescens* s. l., *Prunus spinosa*, *Ruscus aculeatus*, *Rosa canina, Rubus ulmifolius* Schott*,* and *Paeonia mascula* subsp. *russoi*. A different plant composition is observed in Filici forest plot such as *Pinus canariensis*, *P. halepensis*, *Cupressus sempervirens*, *Hesperocyparis arizonica*, *Quercus pubescens* s. l*., Fraxinus ornus, C. creticus*, *Quercus ilex* subsp. *ilex*, *R. aculeatus*, *R. canina,* and *Ampelodesmos mauritanicus*.

Due to the presence of *Quercus ilex* subsp. *ilex* regeneration, in this last area the evolution of the stand towards the evergreen Mediterranean forest is evident. Due to the shading of their canopy, pines promote the growth and development of young oak seedlings. In this area it is advisable to thin the trees in order to encourage the development of oak seedlings when an intermediate age has been reached to promote a possible rotation to the plants that already persist in the plot. The absence of silvicultural practices (with the exception of reforestation with *Pinus* species) has allowed a natural evolution of the area towards a typical Mediterranean forest, not allowing the establishment of invasive species such as *Ampelodesmos mauritanicus*.

Cedrus atlantica *stands*

In Sicily, within the wide reforestation activity carried out since 1950, the Atlas cedar has been less used than other conifers. It has often been used as isolated plant or in small groups, within reforestations with protective purposes; only in some cases pure plants of modest extension have been realized mainly in areas of the mountain of Sicani, Madonie, Nebrodi, Peloritani and, Mount Etna in association with the other conifers already mentioned and mainly at altitudes higher than 800 m.

In the study area, pure stands of *Cedrus atlantica* occupy an area of ca. 65 ha and the altitudinal distribution ranges from 1000 to 1450 m. The cedars were planted around 1960, in the winter period from November to January, with a planting method based on holes of

40×40×40 cm, and with the realization of steps to facilitate planting in areas with high slopes. The stepping stone, or terracing, consists in the movement of a steep ground to avoid landslides, and this also allows the planting.

Most of the pure stands of cedars fall on Monte Gemini (Fig. 4) and Monte Cammarata. While along the southern slope of Monte Cammarata prevails the mixed wood of *Pinus nigra* subsp. *nigra* and *C. atlantica*. Another pure cedar wood is found near the locality of Gargiuffè, at altitudes around 1100 m. The stands consisting exclusively of mesophilic species, such as *C. atlantica* and *Pinus nigra* subsp. *nigra*, are almost all included in areas of ecological suitability.

Despite being artificial stands, pure cedar trees adapt well to the environmental context in which they were planted. This adaptation is due to the fact that these reforestations were made at altitudes suitable for their growth, since are species with a supramediterranean thermotype. Cedar is generally accompanied by *Pinus nigra* subsp. *nigra*, while native species are found in the dominated layer, with a low density. In these areas the cedar occupies the dominant layer, but it can be found a rich lower layer characterized not only by shrubby species but also by mesophilic species such as *O. carpinifolia*, *Sorbus torminalis* L., and *A. campestre*.

The first sampled area of Atlas cedar is located at the foot of Monte Cammarata, on the northeastern slope, about 200 m after the "Romeo crossroads", which divides the road leading to Monte Cammarata from the road leading to Monte Gemini. The area observed is at an altitude of ca. 1330 m, where the stand and the evolutionary dynamics based on how the area had been managed was analyzed. Also in this area the stand of Atlas cedar is mixed with *Pinus nigra* subsp. *nigra*.

This stand rests on a calcareous soil rich in rocky outcrops, where silvicultural practices are not performed. Therefore, after the planting of the seedlings around the 60's, the silvicultural treatments (e.g., pruning and thinning) that could allow the evolution of the stand have not been carried out. The planting density should be 5 × 2 m, with a low natural regeneration, but higher than in other areas of the SCI where the stand is characterized by Mediterranean conifers. In fact, in stands with excessive density, especially the artificial stands of *P. halepensis* and *Cupressus arizonica* and *C. sempervirens*, the renewal is low or even absent, while in areas with stands of cedar with *Pinus nigra* subsp. *nigra*, the renewal is more abundant given the lower density.

Renewal in this area concerns mainly species such as *Quercus ilex* subsp. *ilex*, *A. campestre*, *F. ornus*, *O. carpinifolia*, and also shrubby and herbaceous species such as *Daphne laureola* L., *Rosa canina* L., *Hedera helix* L., and *Rubus ulmifolius*. In open areas, where the presence of cedar is rare, we also find *Prunus spinosa* L. and other herbaceous and shrubby species (Domina & al. 2015). The presence of pastures and an almost absent regeneration of *C. atlantica* should also be noted, while regeneration can be seen in more open areas of the SCI.

An unexpected finding in the area was the presence of three seedlings of *Fagus sylvatica* L. (Fig. 5): two plants 1 m tall and another of about 5-6 m, the latter with a diameter of ca. 7-8 cm. All the plants are found adjoining three individuals of *Pinus nigra* subsp. *nigra*. These seedlings, very close to each other, have been planted by the foresters ca. 24 years ago, together with other 10 individuals in the area, as reported by the Managing Authority of the Park. Of these, only the three individuals, found during the surveys, mana-

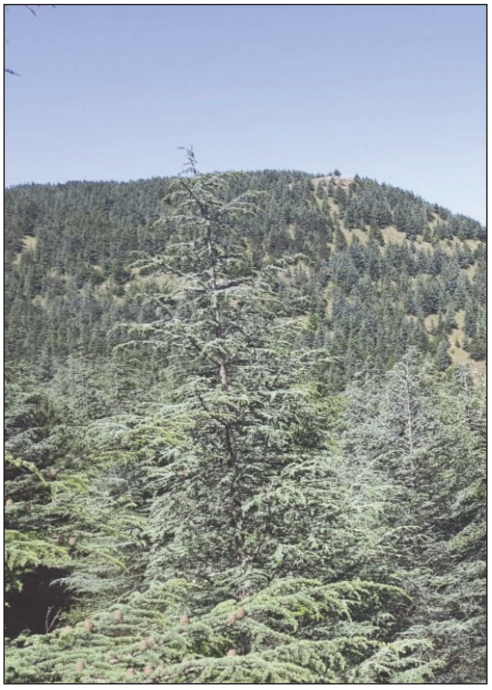

Fig. 4. Cedrus wood on Monte Gemini.

Fig. 5. *Fagus sylvatica* in the undergrowth of *Pinus nigra* subsp. *nigra* reforestation.

ged to take root and develop. This highlights that *F. sylvatica* could develop and grow if supported by careful silvicultural practices in the Monti Sicani Park.

The second sampled area is located on the northern slopes of Monte Gemini at an altitude of ca 1390 m, where the stand of *C. atlantica* and *Pinus nigra* subsp. *nigra* is characterized by trees with a greater height than those of the previous area, with a high rate of growth.

Also in this case the study area is an artificial stand on calcareous soils, where silvicultural practices are absent. The hypothesized planting pattern is 3 × 4 m. The stand is characterized by a precarious stability with poor natural regeneration, due to the high density of *Cedrus atlantica* and *Pinus nigra* subsp. *nigra* trees and also by the dense presence of needles that cover the soil and do not allow other species to settle. Moreover, this high presence of needles is harmful and dangerous in case of arson, but at the same time it acts as a litter, enriching the soil with necessary organic substances.

The species surveyed in addition to those already mentioned, concern species that have settled by natural regeneration, such as *Quercus ilex* subsp. *ilex*, with mild scattered individuals and with a height not exceeding 1 m; *Q. pubescens* s. l., *Ostrya carpinifolia*, *Daphne laureola*, *Rubus ulmifolius*, *R*osa *canina*, *Hedera helix*, *Acer campestre*, *A. pseudoplatanus* L., and *Fraxinus ornus*.

In both areas, the absence of cedar regeneration is due to the fact that this species needs some open spaces to grow up. In fact, the regeneration of the species is noted only close to

clearings and open spaces in order to allow light penetration, whereas in areas where the density is higher, sun rays cannot penetrate and therefore this leads to a lower regeneration.

It has been noticed that in Sicily *C. atlantica* has a strong capacity of growth, confirming that this species is one of the most important species to be used in the reforestation in sub-mountainous and mountainous environment, in order to combine its productive possibilities with the ability to colonize uncultivated lands for environmental recovery practices. This species tends to renew easily under cover, because the seeds germinate normally and in abundance, but the young seedlings are not able to establish themselves because of the high density which determines conditions of scarce light.

These areas, where the planting of the species under examination has been carried out, show a remarkable evolutionary potential, especially in the sampled area near Monte Cammarata characterized by a low density of the plants. The evolutionary potential is represented by oak woodland or mixed coniferous and deciduous woodland, although the abundant foliage cover does not allow this, also hindering natural regeneration.

The best solution would be to support and stimulate the renaturalization of artificial stands, since reforestation has not always been followed by the application of adequate cultural care.

The seedlings of native species are not able to grow due to the excessive density of the tree layer as in the case of coppices at low altitudes where regeneration is almost absent. On the contrary, at higher altitudes, conditions are more favorable with the spread and development of mesophilic species.

Results

In the not thinned area, the degree of coverage of tall trees covers about 90% of the soil, while the remaining 10% is caused by the projection of the canopy of *Quercus ilex* subsp. *ilex* and *Q. pubescens* s. l. that settle in the few spaces left free from conifers. On the contrary, in the thinned area in Filici there is a degree of coverage due to the projection of the canopies of the shrubby and herbaceous layer.

This is a consequence of silvicultural practices that foresters carry out to reduce the dense presence of tall conifers and promote the establishment and development of broadleaf trees. In fact, the forest plot (200 m^2) is characterized by a degree of coverage equal to 70% (projection of the canopies of the shrubs established in the spaces left free by the cuts), 20% by the young seedlings belonging to the herbaceous layer and, about 10% by the crowns of the tree layer, represented by *Hesperocyparis arizonica*, *Cupressus sempervirens* and *Pinus canariensis*.

In both areas the growth of *Quercus ilex* subsp. *ilex* was rather stunted. But while in the not thinned area this aspect is understandable because the plants are covered by tall conifers that do not allow the development of a microclimate suitable for their growth, the situation is different in the thinned area where the wide spaces left free by the silvicultural practices can allow a constant and continuous development of the plants.

Management proposals

The modern management of a forest area is based on the concept of sustainability, in order to avoid possible stresses or modifications and changes, especially due to anthropogenic causes. These could negatively affect the functionality, development, evolution, and establishment of a forest ecosystem (Ciancio & al. 2002).

As can be seen from the observations carried out in the two selected areas, the area in Filici, thanks to the silvicultural practices carried out through funding from some European projects for the improvement and enhancement of the forest stand, benefits and supports a management aimed at ensuring the preservation of forest coenosis and the evolution towards more stable structural forms.

Selective thinnings allow a renewal consistent with sustainable management, favoring the re-naturalization of the reforestations and also the opening of spaces within the area that inhibit coverage by tall conifers, and at the same time allow broadleaf trees their own establishment. The felling of the conifer allows the establishment and gradual replacement of native species without any impact on the landscape.

Alternatively, planting can be considered through localized practices and using species that belong to the native vegetation. Moreover, the cuts have determined the natural renewal of some pines, cypresses and, cedars that allow, together with the establishment of broadleaf trees, the formation of more stable structures and the evolution of the mixed forest.

For this reason, the areas of the Park where there is a high density of conifers, as in the case of the Savochello locality, should be managed by promoting selective cuts that lead to a renewal that reflects the objectives of modern sustainable management and an improvement in biodiversity levels. Felled plants are left on the fall bed and should be transported and placed in appropriate areas, to limit or prevent damage caused by any arson.

The objective of management must therefore be to increase the complexity of the ecosystems, through the conservation and monitoring of the habitats identified and the renaturalization of reforestation.

Artificial forests of conifers characterize much of the territorial mosaic of the site, with stands consisting of young forests with excessive density and degree of coverage between 80 and 90%. The excessive density of these stands does not allow the establishment of spontaneous renaturalization processes that are potentially possible.

Conclusions

This study confirms the need for policies aimed at the management of Sicily's considerable natural heritage. In the few cases in which the allocation of funds from different sources has been successful, there have been targeted practices of silvicultural and management type that have triggered virtuous processes with obvious beneficial effects on forest ecosystems, with reference to the beginning of processes of natural regeneration by native species.

The most evident problem is represented by the lack of application of the laws in force regarding the safeguarding of nature as well as the lack of controls by the Authorities in charge. All this determines a series of abuses that, in the absence of sanctions, are repeated over time with serious damage in terms of loss of plant diversity.

On the contrary, the evident enhancement of the paths in the Park allows a better use by tourists and local users and represents a fundamental basis for the enhancement of the natural heritage of the entire area.

In conclusion, compared to other Sicilian natural areas, the Monti Sicani Park, benefits from some naturalistic and silvicultural activities which, if further implemented, will guarantee an improvement in the health of the woodland over time.

The relationship between density and degree of establishment is very varied, also in relation to the characteristics of localities: almost completely absent in stands with excessive density (cypress trees), more frequent in those with a mixed composition and with a more sparse density (pine forests, cedar forests), but in both cases the degree of coverage of conifers is such as to hinder both the processes of establishment and, consequently, the establishment of the regeneration. In stands of ecological suitability, such as cedar stands, it would be necessary to act through a gradual reduction of density in order to support the spontaneous processes of renaturalization in place or to promote them, if they are not yet present, even resorting to under-planting with native shrub and/or tree species.

In some wooded areas, with low density, at altitudes higher than 1200 m, it would be necessary not to carry out any kind of practices because, in these contexts, there are points that host several Sicilian endemics in priority habitats located in ²Zone A² of the Park.

In addition, the lack of practices revealed in the two sampled areas, as well as in the stands of mixed forests of *Pinus nigra* subsp. *nigra* and *Cedrus atlantica*, could be justified by the fact that at these altitudes there are major snowfalls every year. Thanks to the abundant canopy cover and the high density of the plants, the native species and their syntaxa are safeguarded from these snow events that could lead to their death. We must also consider that the stands located on steep slopes and on the ridges are difficult to manage because of the difficult accessibility and also because of the important role they play in hydrogeological defense.

In places where cutting is recommended, these practices should be performed carefully aiming to: i) support processes of renaturalization; ii) increase the stability; iii) maintain the ecological-structural efficiency of the ecosystem. Examples of practices are selective thinnings and pruning aimed at the release of pre-settled native vegetation under cover of allochthonous.

In the SCI, the species that most hinder the development of renaturalization processes of autochthonous species are the *Cupressus*, due to the high density and the allelopathic litter. The most favorable conditions for the diffusion and development of renaturalization processes are found in pure *Pinus halepensis* woods and mixed with *Cupressus sempervirens* and *Hesperocyparis arizonica* and in mixed forests with *Cedrus atlantica* and *P. nigra* subsp. *nigra.*

Artificial forest renaturalization processes play a key role in recomposing the natural forest landscape, which is currently highly fragmented. Finally, there would also be the possibility of obtaining wood production, albeit transitory, from these reforestations. In this case, biomasses could be obtained with which to feed small plants for the production of energy for the needs of the local population.

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