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STRUCTURE AND MANAGEMENT OF ALEPPO PINE FORESTS

O. Ciancio*, F. Iovino, V. Mendicino***, G. Menguzzato***, A. Nicolaci** and S. Nocentini***
*Dipartimento di Scienze e Tecnologie Ambientali Forestali - Università degli Studi di Firenze
**Dipartimento di Difesa del Suolo - Università degli Studi della Calabria - Cosenza
***Dipartimento di Agrochimica e Agrobiologia - Università degli Studi Mediterranea di Reggio Calabria
e-mails: orazio.ciancio@unifi.it; iovino@dds.unical.it

Abstract

The authors analyze the most prevalent structural types in Aleppo pine (Pinus halepensis Mill.) forests on the Upper Ionian Coast in the Province of Cosenza in order to evaluate the evolutionary dynamics resulting from silvicultural treatments and the forest fires that plague this area.

The structural types found in this area are: even-aged, often resulting from fires on vast areas; pure forest with multi-storeyed structure, deriving from fellings generically defined as "selection cuttings"; two storeyed forests, resulting from selection cutting or clear-cutting with seed trees; mixed stands with an under-storey comprising species typical of the Mediterranean maquis and the upper storey characterized by Aleppo pine. The results obtained reveal some aspects that are peculiar to these forests both with reference to the evolutionary dynamics as well as the relationships among fires, the structural type, and past management.

INTRODUCTION

The structure of a biological system is defined by a series of factors and is characterized by reciprocal actions and interdependencies that comprise a functionally superior, unitary and autonomous whole which differs from the sum of its individual components. In forestry the term structure is used to define the manner in which the individual elements trees, shrubs, grasses are arranged and organized and react to each other and the environment.

A forest's structure is defined by the composition and spatial distribution vertically (the profile) and horizontally of the plants in relation to the dimensions, age and regeneration of the individual components . This gives a "static" idea of the forest and yet, in addition to permitting an understanding of the dynamic process related to management, it makes it possible to assess the forest system's level of complexity in relation to the wealth of species and variety of habitats [1], [2], [3].

Study of structure provides information about the internal organization of the forest and how this relates with the environment; structure is the result of the mechanisms of adaptation, cooperation and competition among the various organisms. Furthermore, it highlights the forest's reactions to different types of stress, climate, human factors, fauna, etc.

The knowledge of the structural types comprising a given biological system leads to a better understanding of its diversity and complexity. Within a single forest we can often recognize different structural situations which are reflected in different micro-habitats and hence changes in the other plant shrub and grasses components [4].

Structural types can be traced to a series of phases through which the dynamic process of the biological system develops. Recognizing these phases makes it possible to assess the effects of the silvicultural treatments implemented over the years in a given area. Thus, it represents the starting point for the definition of appropriate management systems for improving and promoting the structural complexity of the stand and the functional efficiency of the system to the highest possible degree [5].

The aim of this paper is the analysis of the most widespread structural types in the Aleppo pine forests on the Upper Ionian Coast of the Province of Cosenza in order to evaluate the forest system's reactions following silvicultural treatments and the fires that plague these areas.

THE ALEPPO PINE FORESTS

In Calabria the natural origin pine forests are concentrated in the Upper Ionian coastal regions. They do not comprise a single, homogeneous whole, rather they are fragmented areas and alternate with reforested zones with which they cover slightly less than 10,000 hectares. The reforested areas account for approximately 20% of the area.

The Aleppo pine forests are located in the hilly sections area between the basins of the Canna, Ferro, Avena, Pagliaro, Saraceno and Satanasso streams. They grow from sea level up to an altitude of 800-900 meters. Another significant fact is that pine grows in river beds even in areas near the mouths of streams and rivers.

The presence of Aleppo pine is related to the ecology of the species itself, and specifically its xerophilous and hardy nature that is suited to the pedoclimate conditions characterizing the area.

The climatic context is Mediterranean with precipitation levels and temperatures that vary with altitude and the macro-exposure of the slopes.

Mean annual precipitation ranges from circa 500 mm in the area near the sea to slightly more than 1000 mm at the upper growing limit. Annual rainfall is characterized by peaks concentrated in the autumn-winter and marked summer drought. Mean annual temperatures range between 18 and 11°C; the coldest month's (January) means fall between 10.9 and 3.5°C; while for the hottest month (August) they are between 26.7 and 19.9°C.

From the phytoclimatic standpoint the area falls into Pavari's *Lauretum* zone [6], warm and medium sub-zones and to a lesser extent, cold sub-zone.

Natural forests characterize a good part of the area and present highly varied structural and physiognomical types because of the alternation of even-aged and multi-storeyed forests. To these we must add the mixed forests in which the upper layer consists of Aleppo pine and the lower, in some cases, of evergreen oak (*Quercus ilex*) coppices, and in others Italian oak (*Q. frainetto*), Turkey oak (*Q. cerris*) and pubescent oak (*Q. pubescentis*) forests partly of agamic origin. These types are the result of a series of factors (ecological conditions , fires, type of ownership, and historical events) that characterize the study area. The pure, even-aged forests are often the consequence of fires on vast areas; most of the multi-storeyed forests derive from fellings generically defined as “selection cutting”.

The mixed, Aleppo pine and evergreen oak forests developed following the establishment of young pines in small clearings that developed within the coppice due to a series of causes: elimination of large standards; abandonment of the areas used for charcoal-making; pollarding the bigger shoots to produce forage for livestock, which up to the nineteen fifties was particularly abundant. Partly because of the gradual reduction of sunlight, only one pine established itself in these small gaps.

The mixed pine forests with deciduous oaks have the same origins, but are found in different pedoclimatic contexts with respect to the others.

METHOD

The method consisted of two phases.

1. *Identification of the main physiognomical and structural types.*
   To determine the current distribution of forests with Aleppo pine, we referred to a study on the ecology of the species conducted in this area [7]. Through a series of surveys we identified different structural types in relation to the age of the stand, the establishment of pine regeneration and of other species and the type of stand profile.

2. *Study of the structural types by surveys on transects.*
   We marked off seven transects ranging in size from 20 m x 10 m (200 m^2) to 50 m x 20 m (1000 m^2) broken down as follows: one in the even-aged forest; four in the uneven-aged forests and two in the mixed forests. The locations are shown in table 1. Inside each transect we recorded: position (using polar coordinates), diameter at 1.30 m (for all plants exceeding 3 cm), total height and crown base height as well as its projection in relation to the four cardinal points for each plant.

We then calculated the area covered by the crown of each tree and subsequently estimated:

- canopy cover (*cc*) as the proportion of ground area covered by the vertical projection of the crowns, without considering overlap,
- total crown cover (*tcc*) as the sum of all the tree crown projections in percent of ground area,
- index of crown overlap (*ico*) as the difference between total crown cover and canopy cover (*ico = tcc - cc*).

We determined age by taking a core using a Pressler increment borer at 1.30 m from the ground from all the pine trees. On the basis of these data we visualized the structure using the Stand Visualization System (SVS) of the USDA Forest Service (1999).

To determine the number and distribution of the young pines and broadleaved trees, we counted all the plants with diameters of less than 3 cm.

To estimate the volume of the Aleppo pine, evergreen oak and deciduous oaks, we applied the double entry table of the Italian National Forest Inventory [8].

If stumps of previously felled trees where present and in good condition, we measured the diameter and counted the growth rings.

RESULTS

The following structural types were identified and described:

1. even-aged pine forest;
2. uneven-aged, multi- or two-storeyed, pine forests;
3. evergreen oak coppice with scattered Aleppo pines;
4. Italian oak forests with scattered Aleppo pines.

Table 1. Locations of the study areas.

Structural types	Locality	Latitude N	Longitude E	Altitude (m s.l.)	Gradient (%)	Exposure
Even-aged pine forest	Bosco dello Straface	39°54' 59.6"	16°29' 25.9"	600	40	S/E
Uneven-aged multi-storeyed pine forest	Cristali	39°54' 59.6"	16°29' 25.9"	650	25	E-NE
Uneven-aged multi-storeyed pine forest	Cristali	39°54' 57.4"	16°29' 37.5"	620	40	E-NE
Uneven-aged two-storeyed pine forest	Bosco dello Straface	39°57' 45.6"	16°29' 47.1"	550	50	N
Uneven-aged two-storeyed pine forest	Piano di Antuona	39°55' 27.3"	16°31' 48.6"	240	25	S/E
Mixed coppice with evergreen oak and scattered Aleppo pines	La Cersana	39°57' 54.7"	16°30' 19.5"	500	20	N/O
Italian oak forests with scattered Aleppo pines	La Cersana	39°57' 30.1"	16°30' 24.9"	640	35	N/O

Even-aged pine forest

The stand developed after a 1970 fire which involved a vast area and destroyed a mixed pine, evergreen oak and Italian oak forest that had itself been generated after a fire in 1950.

The profile is a single layer cover. The density is high. There is a total of 2625 pines per hectare with diameters of up to 18 cm and heights that reach 9-10 meters, distributed in groups of varying size. The spaces between groups are occupied by lentiscus and *Phyllirea angustifolia.* Pine diameter distribution

follows the typical Gaussian curve with the mode in the 10 cm class. There is also a significant number of small pines (figure 1).

Canopy cover and total crown cover are 83% and 300%, respectively; the index of crown overlap is 217%.

The basal area is 23.77 m^2 ha^{-1}, with a mean diameter of 10.7 cm and mean height of 7.22 m, volume starting from a diameter of 10 cm is 64.3 m^3 ha^{-1}.

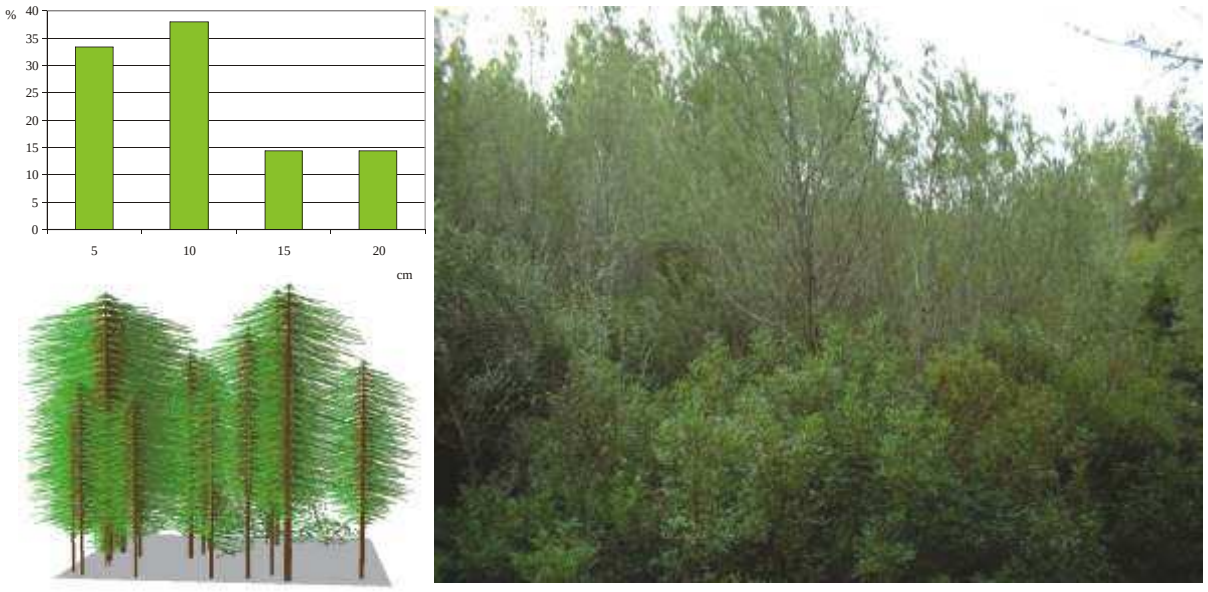

Fig. 1. Even-aged pine forest

Uneven-aged pine forests

We marked off four transects in this stand type: two transects were in privately owned forests and present a multi-storeyed structure; and two in publicly owned forests that had been treated differently and have a two-storeyed structure.

Multi-storeyed pine forest

This type of structure was described within two transects.

The first transect was in a forest in which evolutionary processes are in progress with abundant and diffuse establishment of meso-xerophilous broadleaved species (evergreen oak, flowering ash, maple, *Fraxinus oxyphylla*, pubescent oak, European mountain ash) (figure 2).

The stand is characterized by a structure with four main strata (table 2):

I. the first layer (uppermost layer) is formed by scattered pines (53 ha^{-1}) with diameters exceeding 60 cm, heights up to 20 meters and ages over 60 years;

II. the second layer (upper intermediate layer) alternates single pines and groups of 2-3 pines, approximately 50 years old, with diameters approx. 40 cm and heights approx. 16 m;

III. the third layer (lower intermediate layer) is formed by single pines or small groups of few pines, approximately 30 years old, with diameters ranging from 25 to 30 cm and heights of around 14 m;

IV. the fourth layer (bottom layer) consists of broadleaved trees (10-15 years old) and Aleppo pines. There are 480 broadleaved and 107 pines per hectare.

Table 2. Multi-storeyed pine forest in evolution

	Layer	Age (years)	Np/ha	Dg (cm)	Hm (m)	G/ha (m^2)	V/ha (m^3)
	I	60-70	53	63,1	19,2	16,66	191,8
	II	40-50	187	38,2	16,33	21,4	201,1
	III	25-30	80	25,8	14,02	4,18	30,5
	IV	15-20	107	11,4	9,24	1,09	2,4
Totals	*Aleppo Pine*		*427*			*43,33*	*425,8*
	Broadleaves	*10-15*	*480*	*4,7*	*6,06*	*0,84*	*4*

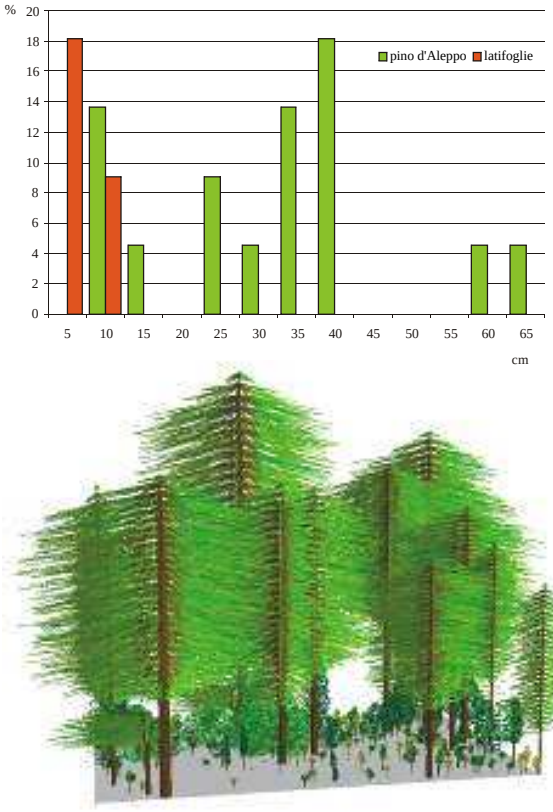

Fig. 2. Multi-storeyed pine forest in evolution

Furthermore, we found approximately 4500 Aleppo pines per hectare with diameters of less than 3 cm occupying the spaces between the bigger trees.

We can presume that the establishment of the broadleaved trees was favored by the good soil conditions and the low intensity of the 1985 selection felling that eliminated less than 50% of the number of trees usually cut on privately owned lands.

The canopy cover is 93%, total crown cover is 114% and crown overlap index is 21%. The undergrowth consists of shrubs typical of Mediterranean maquis with a prevalence of *Phyllirea* that attains diameters of 5-8 cm and heights of 6-7 meters, mixed with lentiscus, wild olive, wild pear and dog rose. Another plant endemic in this zone is Phoenician juniper which colonizes areas where there is no excessive shade.

The second transect was marked off in a practically pure pine forest where a “single-tree selection felling” was carried out around 1985. Here too, the plants are distributed randomly or in small groups.

The profile consists of several layers (figure 3; table 3):

I. the first, and uppermost layer consists of few (30 ha^{-1}) randomly distributed pines, with diameters exceeding 50 cm, heights of 18-20 m and ages ranging from 60 to 80 years;

II. the second layer (upper intermediate layer) comprises single pines or pines in groups of 2-3 (140 ha^{-1}), with diameters from 30 to 45 cm, heights between 15 and 18 m and ages between 40 and 50 years;

III. the third layer (lower intermediate layer) is formed by single pines or pines in groups of 2-3 (130 plants ha^{-1}), with diameters from 18 to 30 cm, heights ranging from 12 to 15 m and ages between 30 and 40 years;

IV. the fourth layer (bottom layer) consists of pine regeneration established after the 1985 selection felling. We counted 8350 plants: of these only 7% have diameters greater than 3 cm and only slightly more than 8% have diameters that fall into the 10 cm class and are between 10-15 years old. They are localized mainly in the gaps of 80 and 100 m^2 that were created after the larger pines were felled, and to a lesser extent, beneath the cover of the taller pines.

Table 3. Pure multi-storeyed pine forest.

Layer	Age (years)	Np/ha	Dg (cm)	Hm (m)	G/ha (m^2)	V/ha (m^3)
I	60-80	30	57,8	18,81	7,86	87,8
II	40-50	140	38,8	16,42	16,53	156,9
III	30-40	130	24,1	13,64	5,95	41,8
IV	15-20	580	4,9	4,13	1,08	0,4
Totals		*880*			*31,42*	*286,9*

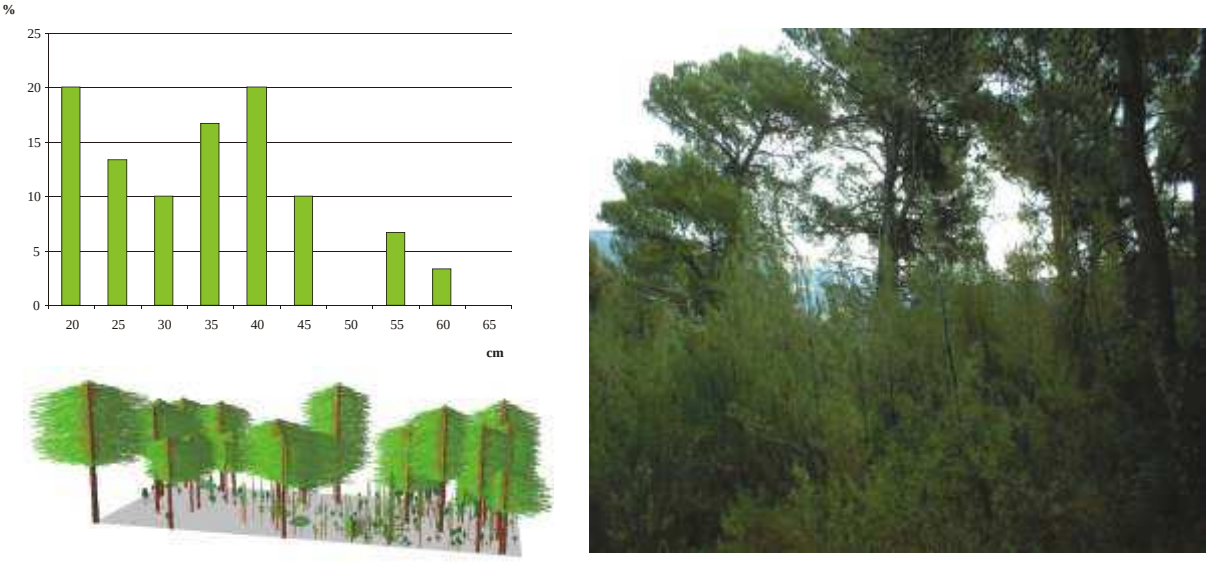

Fig. 3. Pure multi-storeyed pine forest.

Two-storeyed pine forest

Two transects fall into this structural type. The first is in a pine forest that belongs to the municipality of Castroregio that underwent a rather vigorous group selection cutting in the early 1980s; the second transect was marked off in the Amendolara municipal forest, where a clear felling with seed tree retention was carried out in the early 1970s..

In the first transect in the Castroregio municipal forest the stand profile has two layers (figure 4, table 4):

I. the upper layer comprises 35-40 year old pines, distributed in groups of 2-4, with diameters ranging from 11 to 24 cm and heights from 9 to 14 meters. The groups are even-aged;

II. the lower layer is characterized by groups of 2- 4 pines alternating with other groups of 6-7 pines, 15-20 years old with maximum diameters of 10 cm and ranging from 4 to 8 m in height; these pines

developed in the gaps created after the felling of all the bigger trees (30-40 cm diameter) which were usually around 60 years old; each group covers an area ranging from 20 to 50 m^2.

Furthermore, there are 471 pines per hectare whose diameters are less than 3 cm.

The relatively small size of the pines in relation to their age and compared to the other stands, can be related to the area's unfavorable pedological conditions: the soils have a clayey texture with high content of very fine sand and silt; furthermore, the soil is shallow, poorly structured and presents drainage problems that limit root development.

The canopy cover is 72%, total crown cover is 81% and crown overlap index is 9%.

Table 4.Two-storeyed pine forest

Layer	Age (years)	Np/ha	Dg (cm)	Hm (m)	G/ha (m^2)	V/ha (m^3)
I	35-40	580	18,1	9,28	14,93	58,1
II	15-20	362	3,7	4,4	0,4	0
Totals		*942*			*15,33*	*58,1*

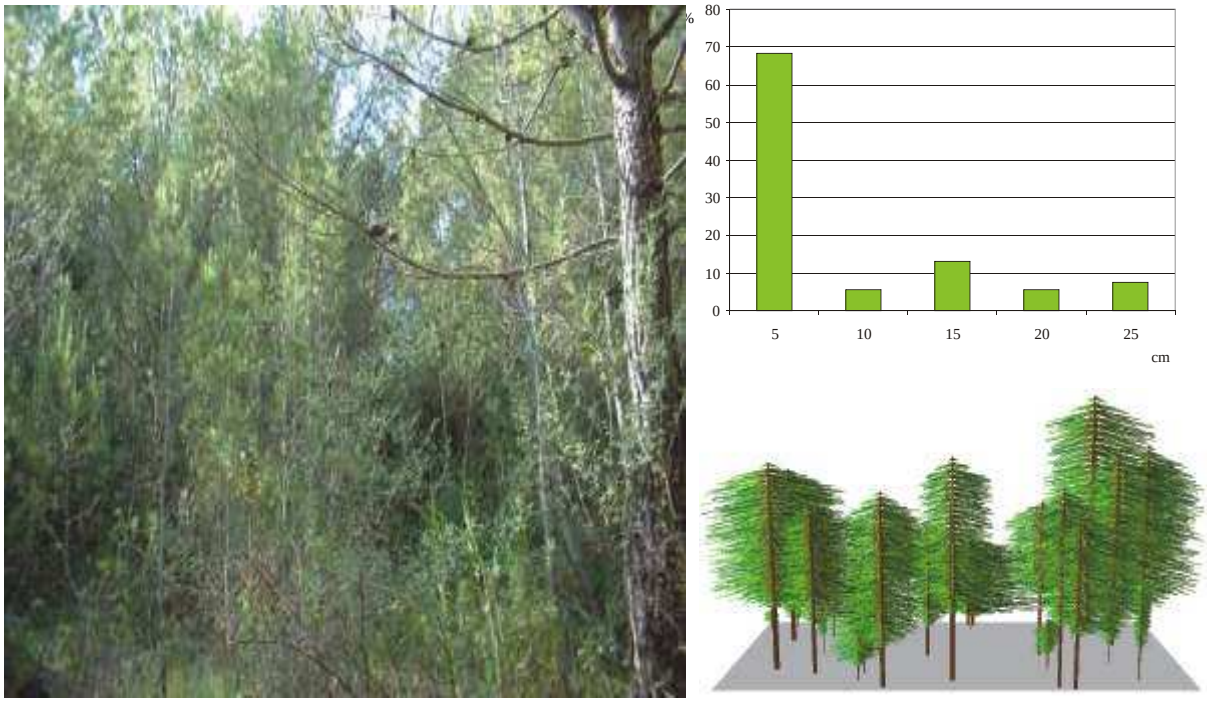

Fig. 4. Two-storeyed pine forest

In the second case the Albidona municipal forest - the transect was marked off in a forest that developed after the previous stand had been clear cut leaving slightly more than 100 seed trees per hectare over an area of approximately 100 ha. The seed trees were cleared in the early 1980s. Here too, the forest consists of two layers (table 5):

I. the upper layer consists of groups of 2-4 trees, between 35 and 40 years of age, naturally regenerated after the felling;

II. the lower layer is formed by groups of 4-10 pines, 20-25 years of age that have established in the gaps left by the felling of the seed trees or at the edges of the lentiscus thickets; in these situations, lentiscus very quickly forms large thickets 2-6 m in diameter with heights even exceeding 2 m, in the spaces where pine regeneration does not occur promptly. Younger pines then developed around these thickets (figure 5).

The pine groups cover areas ranging from 20 to 50 m^2. In the upper layer there are 867 ha^{-1} pines which account for 24% of the total, while the lower layer has 2711. With such a density there is no regeneration of either the pines or other species.

The degree of crown cover is 63%, total crown cover is 133% and overlapping is 70%.

Oak forests with scattered Aleppo pine

We investigated two structural types that are quite common in the study area, both characterized by a significant number of Aleppo pines: 1) Mixed coppice with evergreen oak and scattered Aleppo pines; 2) Italian oak woods with scattered pines.

Table 5.Two-storeyed pine forest

Layer	Age (years)	Np/ha	Dg (cm)	Hm (m)	G/ha (m^2)	V/ha (m^3)
I	35-40	867	16,5	10,93	18,63	77,4
II	20-25	2711	7,8	8,1	12,93	14,5
Totals		*3578*			*31,56*	*91,9*

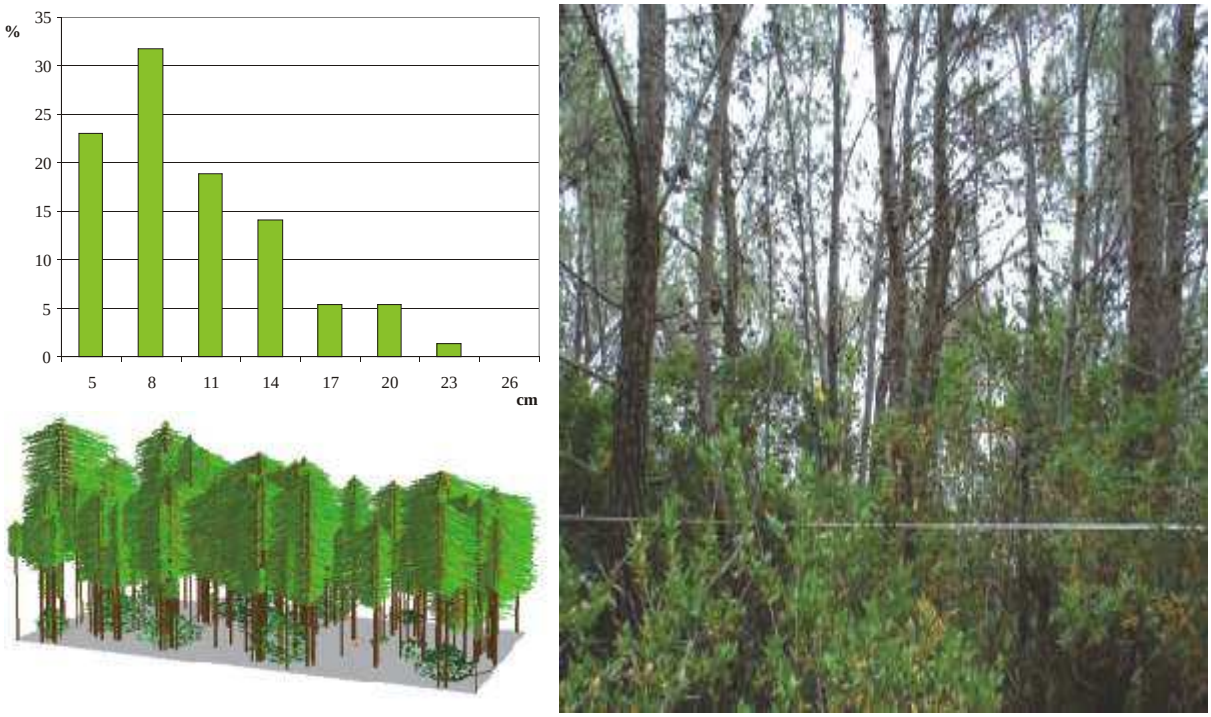

Fig. 5. Two-storeyed pine forest

Mixed coppice with evergreen oak and scattered Aleppo pines

This type is found where the soil is most fertile, at altitudes above 500 meters, on slopes with north-northwest exposures where no fires have occurred. The forest has a two-storeyed structure (table 6, figure 6).

I. The upper layer is formed by 83 Aleppo pines per hectare aged 35-45 years, with diameters from 30 to 60 cm, and heights ranging from 15 to 19 m. The way the pines are distributed on the ground is due to several causes. Felling of large standards, abandonment of the old charcoal-making areas and pollarding of the bigger shoots to produce forage for the livestock that was particularly abundant in the area up to the 1950s, have in time created a series of gaps where dense groups of young pines quickly

established. Strong competition due to the very high density of these groups gradually reduced the number of pine per gap until only one tree was left. The pine canopy cover is now 99%, total crown cover is 265% and the crown overlap index is 166%.

II. The lower layer consists of an evergreen oak coppice mixed with Oriental hornbeam, flowering ash, narrow-leaf ash, *Acer opalus*, with undergrowth of phyllirea, lentiscus and *Arbutus unedus*. The coppice is approximately 50 years old and has well exceeded traditional rotation age (18-20 years, [9]), without any significant silvicultural treatment. The coppice density is 1650 stumps per hectare, 50% of which are evergreen oak.

Table 6. Evergreen oak coppice with Aleppo pine.

Species	nc/ha	np/ha	dg (cm)	Hm (m)	G/ha (m^2)	V/ha (m^3)
evergreen oak	825	1349	13,4	10,17	18,96	125,6
other broadleaved species	825	1584	8,5	7,56	9,13	53,9
Totals	*1650*	*2933*			*28,09*	*179,5*
Aleppo pine		83	41,8	13,9	11,36	113,2

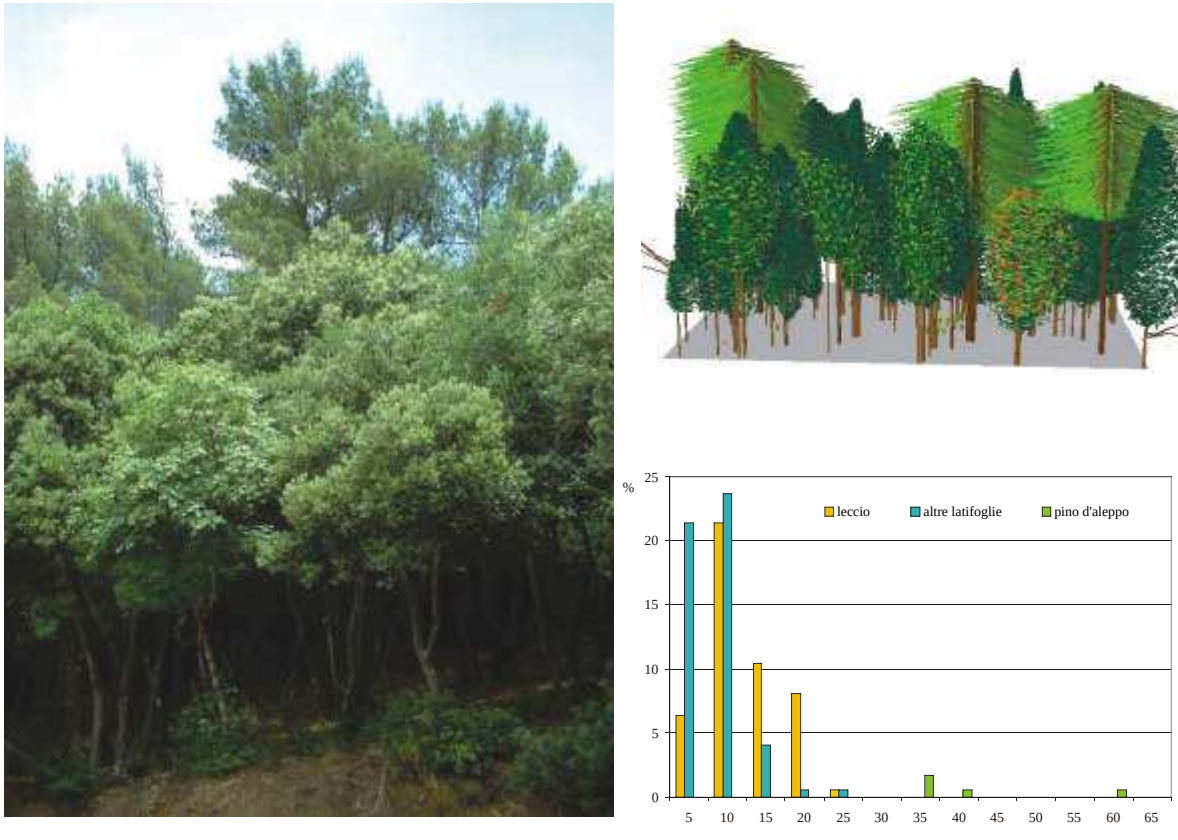

Fig. 6. Mixed coppice of evergreen oak with scattered Aleppo pines

Italian oak forest with scattered Aleppo pines

Italian oak (*Q. frainetto*) forests with scattered Aleppo pines are quite widespread at the pine's upper limit of vegetation. They are characterized by scattered individual pine trees and small groups of pine regeneration throughout the Italian oak stands that are formed mainly stump sprouts.

The stand profile is characterized by (figure 7, table 7):

a) an upper layer consisting of 133 pines per hectare aging from 35 to 45 years, with diameters between 20 and 45 cm and heights between 10 and 12 m.

b) a lower layer consisting of 978 Italian oaks, 45 to 50 years of age, with diameters of up to 18 cm and an average height of 11 m. The Italian oak is associated with European mountain ash, phyllirea, flowering ash and narrow-leaf ash. The Aleppo pines have originated from natural regeneration that established itself in the gaps created by the felling of big Italian oaks from the previous cycle. This phenomenon is still occurring when small, 30-40 m^2, gaps are created following different causes, such as the felling of single oaks or groups of oaks; pine regeneration promptly occupies these gaps.

Table 7. Italian oak forests with scattered Aleppo pines

Species	np/ha	dg (cm)	Hm (m)	G/ha (m^2)	V/ha (m^3)
Italian oak	978	12,4	9,7	11,82	51,3
other broadleaved	1044	6,2	5,68	3,17	10,1
Totals	2933			28,09	61.5
Aleppo pine	133	32,8	15,43	11,26	107,5

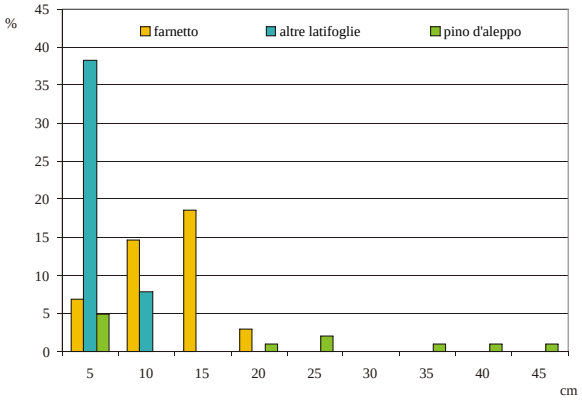

Figure 7. Italian oak forests with scattered Aleppo pines

CONCLUSIONS

This study reveals both the impact of silvicultural treatments on the evolutionary dynamics of Aleppo pine stands and the relationship between fires and structural types. In this area management varies according to ownership and site conditions.

Aleppo pine stand silviculture in the past was mostly based either on “selective cutting” of individual or small groups of trees or clear cutting with seed tree retention. These methods have favored the development of uneven-aged multi-storeyed or two-storeyed stands.

The multi-storeyed pine forests are located on private properties where, in the past individual or small groups of trees over 60 years old with diameters greater than 50 cm were selectively felled. These fellings eliminated approximately 30% of the volume, leaving a standing volume of roughly 200 m^3 ha^{-1}. Aleppo pine promptly regenerated in gaps ranging from 30 to 100 m^2.

Under good soil conditions - deep, well-structured soils with coarse texture and rich in organic substances -, at the higher altitudes and where the selective fellings were of moderate intensity, felling approximately 50% of the bigger plants, evergreen oak and other meso-xerophilous species are entering the stands and have started the evolution of the pine forests towards broadleaf forests. Furthermore, the presence of evergreen oak and Italian oak forests proves that the forest landscape in these regions, at least above 400 meters in altitude, is characterized by these species.

In less favorable pedological conditions - clayey soil with poor fertility - all the trees with diameters greater than 20-25 cm were felled at approximately 20 year intervals. The pine forests that developed there present two-storeyed structures with groups of 50-60 year old pines alternating with groups of 30-40 years. This structural type is also found where clear felling with seed tree retention was done with roughly a 20 year interval between the clear cutting and seed tree removal. In this case natural pine regeneration established in two different moments: immediately after clear cutting and then after seed tree removal.

The even-aged pine forests, on the other hand are the result of either clear cuttings done at particular historic moments, or the consequence of large-scale fires. And, it is precisely to these events and the application of casual fellings that were not always appropriately supported by rigorous silvicultural and management standards, that we owe the natural perpetuation of these forests.

We can conclude that the Aleppo pine forests in the study area present structural types correlated with past management methods. Once again we have a confirmation that each forest has its own history. From the structural standpoint this translates into a broad series of intermediate cases between even-aged and uneven-aged forests. And each case has its own peculiar physiognomy.

It is interesting to point out that a light demanding and non-excessively long-lived species, such as Aleppo pine, is capable of creating stratified structural types through the juxtaposition of small, or even very small, groups of trees, each of different age, shape and size.

In the case in point the forests have more or less complex structures consisting of small, randomly distributed, differently aged groups - with 2 to 20 even-aged trees in each. Therefore, these are not classic, single tree uneven-aged forests, but very small group selection forests consisting of an aggregate of even-aged micro-stands, each covering an area ranging from 20 to 100m^2.

The abundance of uneven-aged pine forests in this area shows that the most widely implemented treatment, while not practiced with any regularity any more, is similar to that recently described by Ciancio et al. [10] for Calabrian pine stands in the Sila mountain range. Similarly to the Calabrian pine stands, management of these Aleppo pine forests is based on a selection cut that was repeated at intervals of approximately 20 years and which was carried out without any systematic planning. This type of “unregulated” and unwritten management belongs to local and traditional knowledge.

Currently, in the publicly and privately owned pine forests there is no active silviculture other than the occasional harvesting of individual trees.

The rediscovery and implementation of the traditional form of management for Aleppo pine stands can help in gaining consensus from the local population and thus contribute to preventing, or at least reducing the forest fires that are practically endemic to this area.

On the basis of our findings it is possible to envision a management approach for the Aleppo pine forests that calls for diversified treatments in relation to the pedoclimate and socio-economic contexts of the area. In the pure pine forests near the coast where, in addition to forest fires, unfavorable environmental conditions do not permit development towards more complex mixed forests, traditional *small group selection cutting* can promote the creation of uneven-aged multi-storeyed or two-storeyed stands.

For the pine forests situated in the pedologically more favorable stations at higher altitudes management should aim at facilitating wider diffusion of broadleaf species mainly oak that even today are still lacking in some areas.

This type of approach enhances structural complexity of the stands and valorizes the typical landscape of this region.

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