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THE ECOLOGY AND DISTRIBUTION OF ALEPPO PINE FORESTS IN THE UPPER IONIAN COAST IN THE PROVINCE OF COSENZA (CALABRIA)

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Abstract

Aleppo pine is a species found primarily in the western sector of the Mediterranean basin. In Calabria natural pine forests are found in the upper Ionian district. The presence of Aleppo pine in this part of Calabria is related to the ecology of the species and specifically its xerophilous and hardy nature, which is suited to the pedoclimatic conditions that characterize the area.

The aim of this paper is to analyze the ecological factors that affect the current distribution of Aleppo pine in the far northeastern part of Calabria (Upper Ionian Coast in the Province of Cosenza), in order to characterize the area's environmental peculiarities, by highlighting those with the greatest significance for the species.

The analysis of the distribution of Aleppo pine forests, along with the results of the pedological surveys and study of the climatic conditions brought to light some peculiar aspects of the ecological context in which the species grows and where the Aleppo pine stands comprise a typical element of the forest landscape in the area.

INTRODUCTION

Aleppo pine (*Pinus halepensis* Mill.) is a species found mainly in the western portion of the Mediterranean basin. However, the large diffusion that has occurred in several countries through reforestation programs makes it difficult, if not impossible, to define its natural area of vegetation with any precision. Aleppo pine forests characterize approximately 10% of the area covered by Mediterranean maquis and forests [1] and, together with hard pine (*Pinus brutia* Henry), cover 6.8 million hectares [2].

Aleppo pine is one of the most typical species found along the warm Mediterranean coasts. In Morocco it is present only in small, separate stands located in areas that are unaffected by the ocean climate, while it is abundant in Algeria and Tunisia [3]. According to Brullo and Furnari [4] there are also small stands in Cirenaica. The species also characterizes the coasts of Spain and Provence in France, which is the northernmost boundary of the area to which it is indigenous [5]. On the Dalmatian peninsula it comprises small stands along the coasts, especially south of Split [6], while it abounds in Greece [7], particularly in the Peloponnesus, in Attica and in Euboia [8]. In the Middle East it is present in the region of Adana on the Anatolian Peninsula; in Syria and along the coasts of Lebanon there are separate stands, as there are in Israel and Jordan [9].

In Italy the biggest forests are situated along the coastal strip of the Gargano Promontory, the Tremiti Islands, Ionian arc of the Province of Taranto and, further south, in the northern part of Calabria.

In addition to these areas, Aleppo pine is found in varying concentrations along the coasts of Liguria, Sardinia, Tuscany, Campania and Sicily. There are Aleppo pine forests, either pure or mixed with broadleaved species, throughout the Italian peninsula in the provinces of Terni (Valle della Nera), around Spoleto, in the province of Rieti and in some inland valleys of the Abruzzo Region [10].

PURPOSES AND METHOD

The purpose of this study was to verify the distribution of Aleppo pine in the far northeastern section of Calabria (Upper Ionian Coast in the Province of Cosenza), in order to characterize the environmental peculiarities of this area, highlighting those of greatest import for the existence and presence of the species.

From a methodological standpoint, the study consisted of the following phases:

- identification of the current distribution of forests characterized by Aleppo pine through 1998 orthophoto interpretation, and subsequent ground surveys to distinguish the forests of natural origin from those created through reforestation. On the basis of this information we proceeded with preparing the relative maps and cartographic documents.
- climatic classification of the territory on the basis of bioclimatic indices and climatic diagrams. For the climate characterization we used mean monthly and annual precipitation statistics from 1921 to 2001 for stations near the studied areas. For temperatures, we used the data from the only measuring station, updated to 2001; for all the other stations we estimated temperatures at the same altitudes as the pluviometric stations using the regression equations calculated by Ciancio [11]. Starting with these values each station was classified in Pavari's phytoclimatic zones, and then for each one we determined Emberger's pluviometric quotient [12], the continentality, summer and compensated ombrothermic indexes developed by Rivas Martinez [13] and the Mitrakos index [14]. For these latter items we evaluated the magnitude of cold stress as the sum of the indices for the months of December, January and February (WCS winter cold stress) and the summer drought stress (SDS) from the sums for June, July and August.
- pedological characterization of the various areas through in-depth study of the information obtainable from the regional soil maps [15] and dedicated campaign surveys.

In order to comprehend the soil-landscape complexity of the Aleppo pine district we conducted pedological surveys of the several study sites. We identified the typical profile for each site through a preliminary study based on the observation of natural slopes and specifically prepared sections. This was then described and sampled for the laboratory tests and analyses. The main chemical parameters were analyzed according to official testing methods and the soils were classified according to both the *Soil Taxonomy* and the *World Reference Base*.

GEOGRAPHICAL CLASSIFICATION OF THE STUDY AREA

The Upper Ionian Coast in the province of Cosenza is the north-eastern part of Calabria, bordering on Basilicata and comprises a large area bounded on the east by the Ionian Sea, on the west by the watershed of the Sinni River basin, on the north by the basin of the San Nicola stream, and on the south by the Raganello stream. It is situated between 40°07' 58" and 39°50' 07" latitude north and between 16°26' 52" and 16°23' 37' longitude east.

It is primarily a hilly and mountainous area, especially in the southern portion, with frequent steep gradients and the usual stability problems related to hydrological (erosion and removal of material, superficial aquifers) and/or geo-mechanical (poor geo-technical parameters) issues. In fact, there is widespread imbalance due to the heterogeneity of the flyschoid deposits characterized by thick layers of fine grained materials alternating with layers of fine and more easily erodable material.

Hydrographically the area lies within the basins of the Canna, Ferro, Avena, Pagliaro, Saraceno, Satanasso and Raganello streams, that drain the area from north to south. These are “fiumare”, rivers that are usually dry for part of the year; they are characterized by short and steep paths in the mountain zone and outlets on the narrow coastal plains where the abrupt change of gradient leads to the development of alluvial cones filled mainly by the watercourse which carves out transitory, interconnected low-waterbeds.

The morphological features of the majority of the hydrographic basins, as well as the presence of large impermeable formations, cause meteoric water to be carried off quite rapidly creating close correlations between the hydrometric regime and seasonal rainfall patterns.

Therefore, the water regime has a very low level of perpetuity with extremely variable flow rates. The hydrometric pattern precisely replicates the pluviometric, involving large amounts of water during the rainy season and remaining with very low or none during summer.

DATA ANALYSES

Climatic Classification

Mean annual precipitation ranges from 500 to 600 mm in the sectors near the coast and increases with altitude with differences, however, between the south-central and northern sectors (table 1). Indeed, in the former at an altitude of 400 meters precipitation is 800 mm, in the latter, even at higher altitudes there is about 100 mm less (figure 1).

Rainfall over the year peaks during autumn-winter (70%) with marked summer droughts (10%) (table 2).

The dry period lasts from May to September-October up to around 300 meters, between June and September at altitudes of 700 meters; and between July and September above 900 meters.

In the stations that receive more rainfall, mean monthly values exceed 100 mm during November, December and January.

Furthermore, there is marked annual variability in all the stations. For example, at Nocara (710 mm annual mean) annual values range from 313 mm to 1520 mm; at Villapiana (504 mm annual mean) the extreme values are 294 mm and 783 mm; at Amendolara (606 mm annual mean) the extreme values are 255 and 1174 mm. In the mean annual and monthly data, temperatures present a thermal gradient around 6 ℃ moving from the coastal areas to higher altitudes.

Mean annual temperatures in the coastal areas vary from 18 and 12℃; in January (coldest month) they range from 11 to 5℃; in August (the hottest month) from 27 to 21℃. The absolute minimum temperature varies from -3℃ at sea level to -11℃ at the upper limit of tree growth.

At all the stations studied, with the exception of Scalo and Montegiordano Scalo, the De Martonne index values are above 20; the Emberger moisture index increases with altitude, going from approximately 50 at Villapiana Scalo to 114 at Albidona (table 3).

Table 1. Mean Monthly Precipitation

	Altitude m s.m.	Period of reference	N° Years	J mm	F mm	M mm	A mm	M mm	J mm	J mm	A mm	S mm	O mm	N mm	D mm	ANNUAL mm
Villapiana Scalo	5	1937-2001	50	67	50	52	31	25	13	12	14	37	60	68	75	504
Montegiordano Scalo	7	1923-2001	77	69	52	58	33	32	18	12	16	40	66	80	78	554
Trebisacce	10	1923-2001	70	77	60	60	36	28	16	13	19	41	71	85	87	593
Amendolara	237	1923-1980	58	81	60	59	38	30	21	14	16	39	76	90	82	606
Francavilla Marittima	272	1923-2001	76	98	79	70	45	34	18	17	22	45	70	95	108	701
Civita	450	1959-1995	37	106	91	83	63	43	27	21	30	50	75	94	125	808
Oriolo	450	1940-1977	37	133	75	86	50	45	30	21	26	57	89	119	109	840
Cerchiara di Calabria	636	1931-1950	20	135	91	82	54	57	35	15	26	55	83	105	137	875
Albidona	810	1923-2001	70	122	83	85	52	50	30	17	24	46	89	118	134	850
Castroregio	820	1923-2001	76	98	71	80	49	45	29	22	24	50	81	105	110	764
Nocara	830	1923-2001	77	102	70	77	49	39	27	20	21	43	70	102	98	718
Middle values				99	71	72	45	39	24	17	22	46	75	96	104	710

Table 2 Mean Seasonal Precipitation

	Altitude m s.m.	Period of reference	N° Years	ANNUAL mm	WINTER mm	SPRING mm	SUMMER mm	AUTUMN mm	WINTER %	SPRING %	SUMMER %	AUTUMN %
Villapiana Scalo	5	1937-2001	50	504	192	108	39	165	38	21	8	33
Montegiordano Scalo	7	1923-2001	77	554	199	123	46	186	36	22	8	34
Trebisacce	10	1923-2001	70	593	224	124	48	197	38	21	8	33
Amendolara	237	1923-1980	58	606	223	127	51	205	37	21	8	34
Francavilla Marittima	272	1923-2001	76	701	285	149	57	210	41	21	8	30
Civita	450	1959-1995	37	808	322	189	78	219	40	23	10	27
Oriolo	450	1940-1977	37	840	317	181	77	265	38	22	9	32
Cerchiara di Calabria	636	1931-1950	20	875	363	193	76	243	41	22	9	28
Albidona	810	1923-2001	70	850	339	187	71	253	40	22	8	30
Castroregio	820	1923-2001	76	764	279	174	75	236	37	23	10	31
Nocara	830	1923-2001	77	718	270	165	68	215	38	23	9	30
Middle values				710	274	156	62	218	38	22	9	31

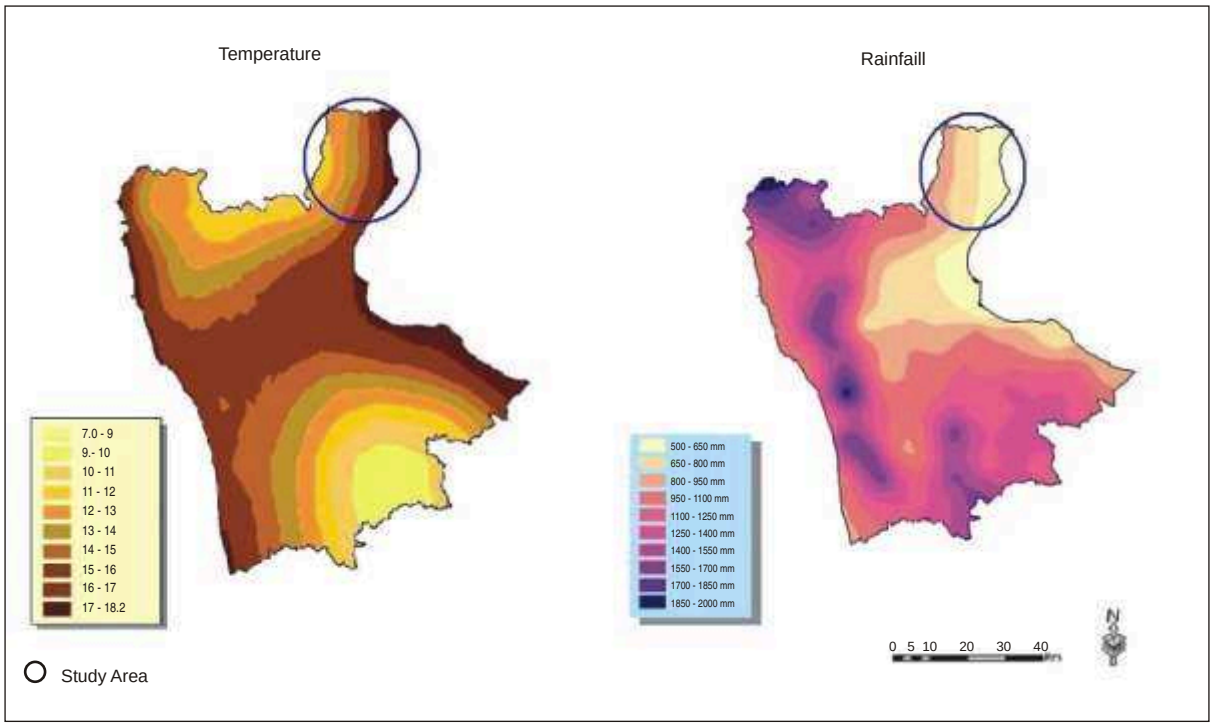

Fig. 1. Breakdown of Precipitation and Temperature Values in the Province of Cosenza

Table 3. Bioclimatic indexes for the sites in the Upper Ionian Coast in the Province of Cosenza

	Altitude m s.m.	De Martonne P/T+10	Emberger P/(M2-m2) x100	Ic (Rivas Martinez) Tmed.m.+c. - Tmed.m.+f.	Ios2	Ios3	Mitrakos	
							MCS (Dic.+Gen.+Feb.)	MDS (Giu.+Lug.+Ago)
Villapiana Scalo	5	19	48	16	0.5		40	230
Montegiordano Scalo	7	20	55	17	0.5		40	202
Trebisacce	10	21	59	17	0.6		40	204
Amendolara	237	23	65	17	0.6		80	198
Francavilla Marittima	272	27	76	17	0.8		88	182
Civita	450	32	93	17	1.1	1.2	112	138
Oriolo	450	33	97	17	1.0	1.1	112	144
Cerchiara di Calabria	636	37	109	18	0.9		150	148
Albidona	810	38	114	18	1.0	1.2	176	160
Castroregio	820	34	103	18	1.1	1.3	184	138
Nocara	830	32	97	18	1.0	1.1	184	162

The Mitrakos drought stress index values (MDS, Monthly Drought Stress) were highest along the entire Calabrian Ionian slope, at least at the lowest altitudes and decrease as altitude increases. Up to altitudes of around 300 m the values are above zero for six months (April - September), the period decreases to four months (May - August) up to 600 m and then to three (June - August) at the pine's upper limit of vegetation. Monthly cold stress values behave in the opposite way: they are above zero for four months (December - March) up to 300 m; six months (November - April) up to 600 meters, and eight months (October - March) to the upper limit of pine vegetation. The typical Mediterranean nature of the climate is shown by the Rivas Martinez ombrothermic index, with an oceanic macrotype, as per the continentality index (Ic) by the same author.

From the phytoclimatic standpoint, the area can be classified in Pavari's *Lauretum* zone; in particular, the majority of the pine forests fall into the warm and intermediate sub-zones, that correspond to Quezel's thermo-Mediterranean and meso-Mediterranan belts [16] and to a lesser extent into the supra-Mediterranean cold zone, where in some areas the Aleppo pine is mixed with evergreen oak and Italian oak.

Pedological classification

The Aleppo pine forests are generally found on soils with sandy and marly clayey substrata. The complexity of these substrata is due to a very evident stratigraphic alternation that causes a certain degree of spatial variability of the soils, going from coarser (sandy) to finer (clayey) textures.

Most of the forests grow on soils with textures ranges from loamy to sandy-loamy with frequent (15 - 35%) well structured skeleton in horizons A and B; depth varies according to the morphology of the slopes and human activities that have affected the forests (cutting and fires). It ranges from shallow (<50 cm) (profile 6) to moderately deep (up to 1 meter) (profile l) soils (figure 2). On the lower parts of the slope, where there are generally evident processes of accumulation, or in the areas which, historically, are less affected by erosion thanks to better forest management, it is possible to find deep (> 100 cm) and more evolved soils (as confirmed by the presence of calcic horizons) (profile 2) [17].

The calcic horizon, is evident in both the deep (profile 2) and moderately deep (profile 1) soils. Profile 3 represents an intermediate evolutionary situation because there are no carbonate accumulations.

From the hydrological standpoint the soils present good conditions of permeability and drainage. The water balance, calculated according to Thornthwaite's method [18], shows a water deficit from June - September for profiles 1, 2 and 3, whereas profile 6 soil presents a longer period of deficit lasting from May to September (figure 4).

From the chemical standpoint, the soils present sub-alkaline to alkaline reactions (pH 7,4-8,4). The alkalinity is due to the presence of calcium carbonate and not salts. Thanks to the buffer effect of the organic matter, the sub-alkaline reaction on the surface horizon, becomes alkaline in the sub-surface horizons.

Soluble salt content is within the normal range. Organic matter content varies in relation to the type of forest and management method. In profile 2 it is high, it decreases in profiles 1 and 3, and is low in profile 6.

Fig. 2. Typic Eutrudept, fine silty, mixed, mesic (USDA). Aleppo pine forests with elements of Mediterranean maquis

From the taxonomic standpoint the profile 1, 2, 3 and 6 soils fall within the order of Inceptisols in the Soil Taxonomy classifications, whereas for the WRB (World Reference Base) it is primarily Haplic Calcisol according to whether or not the calcic horizon is differentiated.

The soils in the marly clayey substratum profile 4 (figure 3), are characterized by a basically fine texture. In fact, these are clay-loamy soils with much silt and very fine sands which are very similar to silt insofar as physical behavior is concerned.

Fig. 3. Typic Endoaquent, fine silty, mixed, (calcareous) mesic (USDA). Aleppo pine forest with elements of Mediterranean maquis

Fig. 4. Typic Haploxerept, fine silty, mixed, thermic (USDA). Aleppo pine forest with elements of Mediterranean maquis

They are shallow (< 50 cm) poorly structured soils, characterized by a gray color due to the lack of interconnected porosity (pores that are not connected to each other), leading to hydromorphism, that limits the development of the root apparatus. The very slow drainage of these soils is the cause of the frequent erosive phenomena that occur in the area. The amount of available water is definitely low. According to Thornthwaite's method the soils present a water deficit from May-September. In this case too, they are calcareous soils, with good organic matter content in the shallow, sub-alkaline surface horizon. From the taxonomic standpoint they belong to the order of Entisols (poorly developed soils) as per the Soil Taxonomy (typic Endoaquent), while for the WRB they are Calcaric Cambisol.

In addition to these two types, which are the most common, on smaller areas there are soils in the sandy non-calcareous substratum that lay on the sandy calcareous soil (profile 5). They are well-structured, with a sandy-loamy structure, with good porosity, permeability and drainage. They are shallow (< 50 cm), neutral and have good organic content. They are classified as Mollisols and Leptsols according to the Soil Taxonomy and WRB, respectively.

Along river shores, Aleppo pine grows on very coarse, non-pedogenized alluvial deposits. Its survival is contingent upon the development of the root apparatus that obtains water directly from below the river bed (figure 5).

Fig. 5. Aleppo pine on the banks of the Saraceno stream

Table 4. Pedological characteristics of the principle types of soil

	Pedon	Soil depth	Evolution of sub-superficial soil layers	Physical and chemical characters					Water deficit	
				Organic substance	Reaction	Total Carbonates	Active Lime	Drainage		
Sandy-calcareous soils	P1	Moderately deep (50 -100 cm)	Differentiation of a calcic horizon (Bk)	High	from Subalkaline to Alkaline	Very calcareous (12.3%)	Low (3.5%)	Good	June – Sept.	Pure Aleppo pine stand
	P2	Deep (100 – 150 cm)	Differentiation of a calcic horizon (Bk)	Very high	from Subalkaline to Alkaline	Very calcareous (11.9%)	Low (3.6%)	Good	June – Sept.	Aleppo pine stand with widespread renaturalization
	P3	Moderately deep (50 -100 cm)	Differentiation of an alteration horizon (Bw)	High	from Subalkaline to Alkaline	Very calcareous (12.5%)	Low (3.4%)	Good	June – Sept.	Quercus frainetto stand with scattered Aleppo pine
	P6	Shallow (25 – 50cm)	Differentiation of a calcic horizon (Bk)	Scarce	from Subalkaline to Alkaline	Very calcareous (12.5%)	Low (4.2%)	Mediocre	May– Sept.	Pure Aleppo pine stand
Sandy non calcareous soils	P5	Shallow (25 – 50cm)	Differentiation of an alteration horizon (Bw)	Very high	Neutral	Not calcareous (0%)	Absent (0%)	Good	June – Sept.	Quercus ilex coppice with scattered Aleppo pine trees
Marly clayey soils	P4	Very shallow (<25cm)	Absence of horizons	High	from Subalkaline to Alkaline	Very calcareous (13.2%)	Moderate (5.4%)	Slow	June – Sept.	Pure Aleppo pine stand

Distribution of Aleppo pine forests

In the study area, the Aleppo pine forests distinctly and differently characterize the three sectors in which it is possible to identify the Upper Ionian Coast of the Province of Cosenza (figure 6). On the whole they cover an area of approximately 10.000 hectares of which 20% are reforested and account for more than 50% of the forested area (18.000 hectares) of the entire territory that presents a tree density index of 26% (an area of 69.460 hectares).

In the southern sector the Aleppo pine comprises forests on vast areas, in the basins of the Satanasso stream, the Saraceno River and the Straface stream.

The pine forests cover approximately 5.200 hectares of which 95% are of natural origin. The stands extend from sea level (figure 7) to an altitude of approximately 900 m where the pine is often associated with Italian oak and other mesophytic broadleaved species. In this sector the pine forests are found mainly on very steep slopes with south-western exposure where farming is practically impossible.

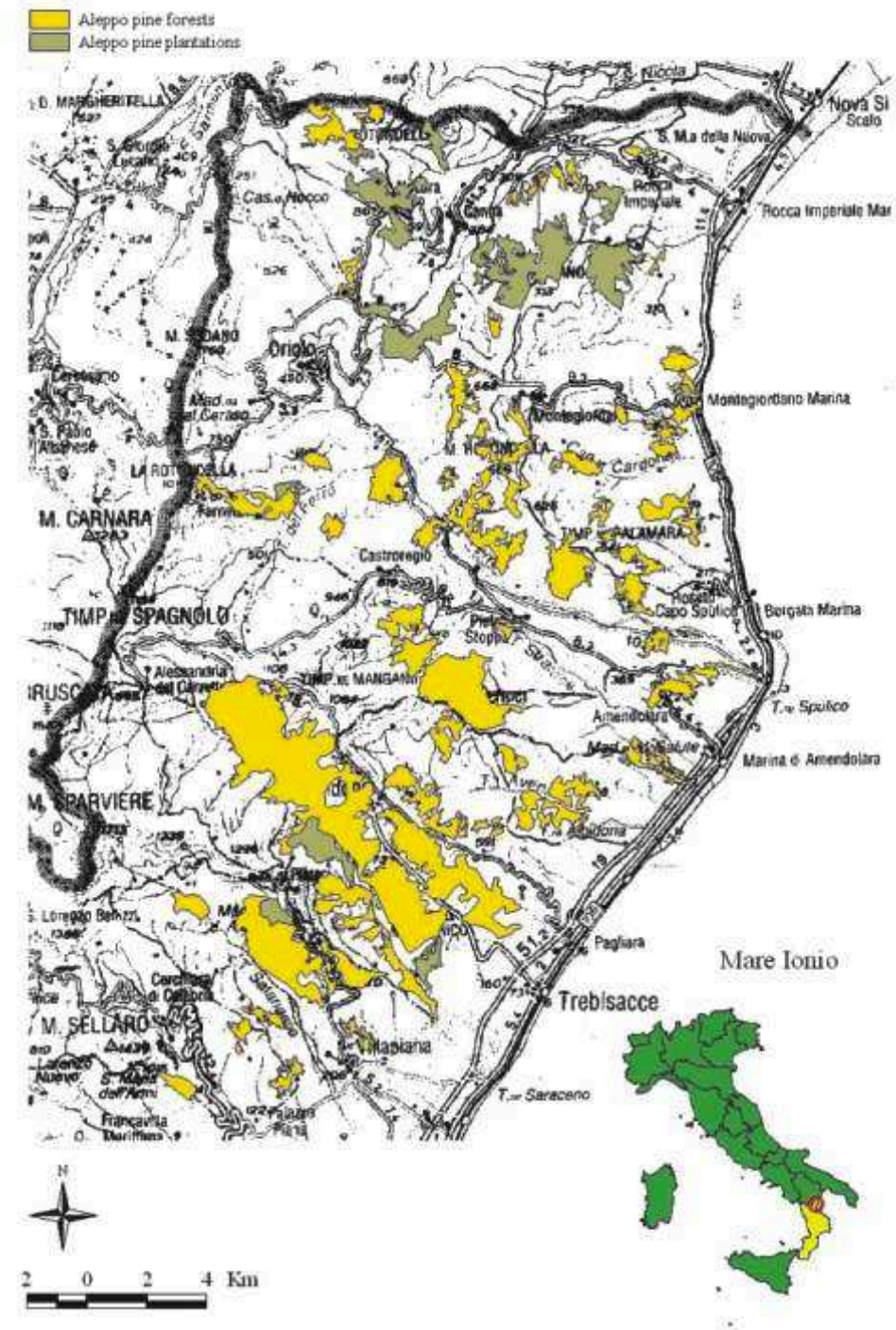

Fig. 6. Distribution of Aleppo pine Forests in the Upper Ionian Coast1

Fig. 7. Aleppo pine on the water's edge

The largest forested area is on the hydrographic left of the Saraceno river basin where the pine forests comprise an almost uninterrupted single complex of approximately 2400 hectares of almost entirely natural origin. To the south, in the Santansso stream basin, still on the left slope, they cover a large area of nearly 600 hectares. To the north, in the Straface stream basin there are several areas covering a total of about 750 hectares. The largest is in the hydrographic right and covers 150 hectares. These stands, that are now separate, are what remains of the large “Straface forest” described by Sisci [19], that has gradually been eroded due to continuing forest fires.

In the central sector the feature peculiar to the pine forests, which here too are almost entirely of natural origin, is the marked fragmentation of the several stands which, except for a few areas, comprise areas of less than 50 hectares. On the whole, there are approximately 2000 hectares, most of which are in the Ferro stream basin and extend from the sea to an altitude of nearly 900 meters near the town of Farneta. The fragmentation and the smaller sizes of the pine forests in this area are due to the good morphological conditions that have permitted the land to be farmed (mainly seed crops, pastures and olive groves) to the detriment of many forested areas (figure 8).

Fig. 8. In areas with more favorable morphological conditions the pine forests were replaced by seed crops and or pastures (left), and in some cases by special crops (right).

As in many parts of Calabria and other regions in Southern Italy, the forests were destroyed starting in the second half of the XVIII century following a series of socio-economic and political events, including population growth and the subsequent need to dedicate ever larger parts of the land to farming.

The northern sector, on the other hand, is characterized by the prevalence of reforestation, most of which was done starting in the second half of the last century. The natural stands (for a total of 370 hectares comprise moderately sized forests (generally not bigger than 30 hectares) in areas with steeper slopes and share the land with seed crops, pastures and other farm crops. The artificial forests (slightly more than 1300 hectares), extend over larger areas ranging from 200 to 400 hectares. The majority fall within the hydrographic right of the Canna stream basin and extend from areas near the shore to altitudes of around 850 meters. Here, where the morphological conditions are even more favorable for farming, destruction of the forests has been even more intense.

One feature common to all three sectors is the great ease with which the pine colonizes riverbanks, even in areas near the mouths where they comprise even very dense nuclei with several age groups, related to intervals between floods.

CONCLUSIONS

The current distribution of Aleppo pine forests in the study area is related to the ecological context and human impact (management methods, fires, changes in land-soil use).

The analysis of the climatic and pedological elements correlated with the distribution of the pine forests has evidenced some factors of special ecological significance.

In spite of marked pedological variability, the forests grow on both sandy and clayey texture soils, of different depths (from deep to shallow), with different organic contents and levels of fertility. Where the pedological conditions are favorable (well-conserved soil) the evolution of the pine forests towards other types (prevalently evergreen oak forest) (Figure 9) is affected only by human actions which, in relation to the various management methods trigger either renaturalization processes or the perpetuation of the pine forest. Management methods that involve highly intensive treatments (clear-cutting with reserves) on large areas as well as fires lead to soil erosion and hence the perpetuation of the pine forest (figure 10). The evolution of the forest is also affected by clayey, often highly eroded (shallow), poorly structured soils with hydromorphic problems. In these soils the water deficit was the longest (April September) and reached very high values.

Fig. 9. The mixed forest with evergreen oak and other broadleaved species flourishes in areas with favorable pedological conditions.

Fig. 10. In difficult morphological conditions (steep slopes) the pine forests extend over vast areas that are not suitable for farming.

Minimum mean annual rainfall is 500 mm with a typically Mediterranean distribution: approximately 70% in autumn-winter, 20% in spring, with a maximum of 10% in summer and marked annual variability. These conditions, together with the duration and intensity of the water deficit of the soils, confirm the Aleppo Pine's considerable resistance to drought stress that is related to a marked reduction in transpiration as an effect of the closing of the stoma [20]. A further confirmation of the species' ability to withstand stress conditions comes from the values and duration of the Mitrakos drought stress index, which are higher than zero for a period of six months.

The thermal limit is obtained from the mean of the monthly minimum temperatures at the upper limit of the pine's vegetation area (850-900 meters), which in January drops below 2°C.

The analysis of the parameters relative to the pedoclimatic conditions of the various sectors has revealed the broad range of variability and the hardiness of the species, that grows from sea level up to 900 meters, thus forming the distinguishing element of the forest landscape in this part of Calabria.

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