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AVAILABLE SOIL WATER CAPACITY AS A DISCRIMINANT FACTOR IN MIXED OAK FOREST OF CENTRAL ITALY

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Abstract - Soil water content is a critical factor in Mediterranean forest vegetation, especially in areas subjected to prolonged summer drought where winter and autumn rainfall are the main sources of water. Available soil water capacity (AWC) is the maximum amount of water available for plants that a soil could possibly contain. Each soil has a specific available water capacity, however, most of the published literature on AWC refers to agricultural settings, although the interaction between the soil and the vegetation dynamics has long been recognized. The aim of this study was to investigate whether this edaphic factor could be discriminant in species assemblage of communities belonging to the thermophylous oak forest (order *Quercetalia pubescentis*). Thirty-two vegetation relevés and soil profiles were carried out in five different sites, with a similar pluvio-thermic regime, located in the sub-coastal belt of Latium, Central Italy. From the physical-chemical analyses of soil profiles, the AWC values, of the related relevés, were calculated. Multivariate statistical analysis was applied to the vegetation surveys, using Cluster Analysis from which a classification in three different clusters was obtained; subsequently the AWC values were grouped according to the classification obtained. Analysis of variance was used to test similarity and the output pointed out a significant difference among the three clusters ($F=6.35$; $P<0.05$). As further examination based on flora composition, Ellenberg indicators and Chorotypes were used to investigate the ecological differences among the three vegetation patterns obtained from the Cluster Analysis. Results demonstrated that AWC may be a discriminant factor in the species composition of the investigated woodlands and that differences between the resulting plant communities were also assessed by the ecological indicators. In addition, AWC was positively correlated with Ellenberg soil moisture indicator.

Key Words - Deciduous oak forest, soil available water capacity (AWC), Ellenberg indicators.

INTRODUCTION

Ecologists have long been intrigued by the role of environmental factors in forest vegetation, because the overlapping of the species niches, which frequently occurs in deciduous forest (Whittaker, 1975), could hide discriminant factors responsible for species assemblage. According to phytosociological criteria the species patterns follow a general long-term codified model. However, it may be useful to explore the possibility of direct significant relationships between environmental factors and vegetation pattern. Following the resource-ratio hypothesis of Tilman (1985), it is necessary to know what the limiting resources are in a community.

In Mediterranean regions, where often the ground water is pumped up for water supply, the small amount of water supplied by rainfall during summer cannot recharge the aquifer; water stored in the soil can be assumed to be an important limiting soil resource in several habitats. Thus, it may be particularly interesting to investigate on soil Available Water Capacity (AWC), this being the capacity of the soil to hold water available for use by most plants and that can be readily absorbed by plant roots.

Soil Available Water Capacity is the maximum amount of water, available for plants, that can be stored in the soil. This water amount is necessary to sustain the plants between rainfall events; thanks to its water storage, the soil can effectively buffer the plant root environment against periods of water deficit. So, AWC may be a discriminant factor within the plant communities both at a meso and at a microscale level (Ciavatta & Vianello, 1989). Measurements of AWC have been proved to be an accurate method to evaluate the amount of water a soil could provide to plants (Sanesi, 2000). Although the interaction between the soil and the vegetation dynamics has long been recognised (Blasi *et al.*, 1995), most of the published studies on AWC refer to agriculture settings (Piccolo *et al.*, 1996; Girona *et al.*, 2002).

Previous studies have noted a strong relationship between soils with high water availability and mesophylous communities in coastal areas, where the high water retention capacity of certain soils, often associated with the presence of a fluctuating water table near the surface, seems to help mesophytic species to overcome the seasonal aridity of the Mediterranean climate (Dowgiallo & Vannicelli, 1993; Dowgiallo *et al.*, 1997, Dowgiallo & Bottini, 1998).

To investigate the relationship between vegetation and environmental factors, Ellenberg ecological indicators, which summarise a complex of environmental parameters, are often used in plant ecology research (Diekmann, 1995; Schaffers & Sykora, 2000). Ellenberg classification has also been used to compare different plant communities and to relate vegetation patterns to environmental changes (Duprè & Diekmann, 1998).

STUDY AREAS

Aims of this study were to investigate whether:

1) Different silvofacies of the thermophylous oak forest with *Quercus cerris* and *Quercus frainetto*, belonging to order *Quercetalia pubescentis*, have different mean values of AWC.

2) Soil AWC could be related with biological and environmental indicators, such as chorotypes and Ellenberg indicators, in describing differences in the silvofacies.
3) AWC values could be correlated with Soil Moisture indicator (F), which is the Ellenberg indicator of soil water content.

The study areas are located in the sub-coastal belt of central-southern Latium: Gattaceca (N 42°05'; E 12°50') Casteporziano (N 41°74'; E 12°40'), Tre Cancelli (N 41°47'; E 12°72'), Padiglione (N 41°57'; E 12°22'), Circeo (N 41°37'; E 13°04') (FIGURE 1).

They are characterized by a typical Mediterranean climate regime with summer drought ranging from 1 to 3 months (FIGURE 1). Thirty-two phytosociological relevés and soil profiles were carried out in these five different sites.

In all sites the vegetation was composed by a dense deciduous forest with a mixed tree layer dominated by oaks (*Quercus cerris, Quercus frainetto* and others) and a variable undergrowth of shrubs and herbs (175 species in total: see TABLE IN APPENDIX).

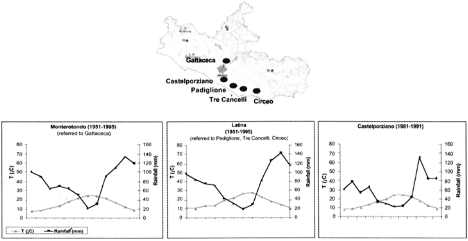

FIGURE 1 - Location of the study sites and ombrothermic diagrams.

METHODS

Vegetation

Multivariate statistical analysis, using the software Biodiversity Pro (McAleece, 1997), was applied to the vegetation data matrix using presence/absence of species. Cluster Analysis was used, selecting the Complete Link as Euclidean Distance procedure.

Values of Ellenberg indicators-Light (L), Temperature (T), Continentality (K), Soil Moisture (F), Soil Reaction (R), Nitrogen (N) -, site based weighted averages, (Ellenberg, 1979; Pignatti *et al.*, 2001) and chorotypes, weighted on species frequencies, were the investigated ecological indicators. Chorotypes scheme and species nomenclature follow Pignatti (1982).

A Floristic Mediterranean Index was also calculated as ratio between 'Eurasiatic/Stenomediterranean + Eurymediterranean' chorotypes.

Soils

Physical-chemical analyses: Analyses were carried out following standard laboratory methods of the Soil Science Society of America (S.S.S.A., 1996). Soils were analysed for: pH (1:2.5 soil to water ratio), extractable P (Olsen method), extractable bases (1 N ammonium acetate extraction and atomic absorption spectrophotometry analysis), organic matter (Walkley-Black method), total N (Kjeldhal method), particle size composition (densimetric method). All the above mentioned parameters were analysed as they provide information on the variability of soil types which are often related to plant communities. Soil samples were analyzed up to one meter depth. AWC was estimated using the following equation proposed by Salter & Williams (1969), based on textural composition and % of organic matter: AWC (H2O mm/soil depth cm) = 1.475 - 0.010 (% coarse sand) + 0.011 (% silt) + 0.138 (% organic carbon). Diagnostic horizons as well as soil profiles were classified to the subgroup level according to the Soil Taxonomy (Soil Survey Staff, 1975 and 1998).

Soil Moisture Regime: The soil moisture regime is an important property of the soil as it refers to the presence or absence of water availability for plants during different periods of the year. Thus a horizon can be considered: moist when the water is held at a tension less than 15 atm (plants average wilting point) but more than 0 atm; dry when the moisture tension is above 15 atm or belove the field capacity (the amount of water a soil can hold against the pull of gravity). The soil moisture regime is influenced by climate, as well it can be also affected by many other factors such as dissolved salts, slope, soil porosity, etc. (Sanesi, 2000).The thermo-pluviometric characteristics were taken from data collected by the meteorological stations located nearby the study areas: Latina, Castelporziano and Monterotondo (Ministero dell'Agricoltura e Foreste; Blasi, 1994). For the profiles studied the soil water balance was estimated according to Thornthwaite & Mather (1957) using thermo-pluviometric data and AWC values.

Statistical treatments

The AWC values were grouped according to the obtained cluster classification. Data distribution allowed us (see results) to use the analysis of variance (ANOVA) to determine if the 3 clusters had the same mean.

Relationship between Ellenberg Soil Moisture (F) and soil AWC parameter was tested with Spearman rank-order correlation, being 'standard' correlation assumptions not applicable.

The spread of the data set, for each cluster, is displayed as the median of the soil profiles for texture, organic matter, AWC, and soil water balance (representative profiles). Statistical tests were undertaken with Minitab™ 13.0 statistical software (2000).

RESULTS

Vegetation

Classification:

From Cluster Analysis a classification in three different clusters was obtained (FIGURE 2), representing different silvofacies of 'Tyrrhenian oak forest' all belonging to the association *Echinopo siculi-Quercetum frainetto* Blasi et Paura 1993 nomen inv., order *Quercetalia pubescentis* Br.-Bl. 1941; which describes deciduous thermophylous vegetation with large component of Mediterranean species emerging particularly in the third cluster (TABLE IN APPENDIX). Species assemblage: the three clusters were distinguished by presence and abundance of the following species, whose autoecology indicates a different mesophily rate among the three clusters, decreasing from I° to III°:

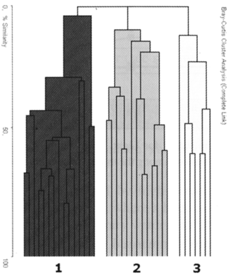

FIGURE 2 - Dendrogram from Cluster Analysis: three clusters of relevés with a different mesophily rate are highlighted.

Cluster 1 – *Carpinus orientalis* silvofacies: Diagnostic species: *Carpinus orientalis, Anemone apennina*. Presence of *Sorbus torminalis, Malus sylvestris, Cornus sanguinea, Melittis melissophyllum, Alnus glutinosa, Fraxinus oxycarpa, Carex remota.*

Cluster 2 – *Crataegus monogyna* silvofacies: Diagnostic species: *Crataegus monogyna, Lonicera etrusca*. Presence of *Pteridium aquilinum, Viola suavis, Erica arborea, Arbutus unedo, Asphodelus aestivus;* high frequence of *Quercus robur.*

Cluster 3 – *Phillyrea latifolia* silvofacies: Diagnostic species: *Phillyrea latifolia, Pistacia terebinthus, Carex distachya*. Presence of *Cistus salvifolius, Erica scoparia, Cercis siliquastrum, Juniperus oxycedrus, Acer monspessulanum;* high frequence of *Quercus pubescens*.

Ecological Indicators:

Ecological Ellenberg L, T, K, F, R, N indicators displayed differences among the three clusters: Light and Temperature increased, while Soil Moisture and Nitrogen indicators, as well as Continentality decreased along the three clusters; Soil Reaction showed a slightly higher value in the third cluster (FIGURE 3).

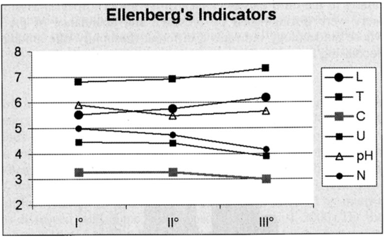

FIGURE 3 - Ellenberg indicators values for Light, Temperature, Continentality, Soil Moisture, Soil Reaction, Nitrogen exhibit differences among the three clusters similar to the ones shown by the AWC values.

Chorological indicators:

Results for chorotypes are summarised in TABLE 1. Eurasiatic contingent was largely prevalent in the most mesophylous vegetation cluster (I°) and decreased in the others, while stenomediterranean elements showed an inverse trend. Large distribution species presented low values in the first cluster and increased in the others, indicating less degraded condition of the most mesophylous vegetation cluster. The Floristic Mediterranean Index exhibits differences among the three clusters, highlighting the dominance of the 'Mediterranean' chorotypes in the third cluster (FIGURE 4).

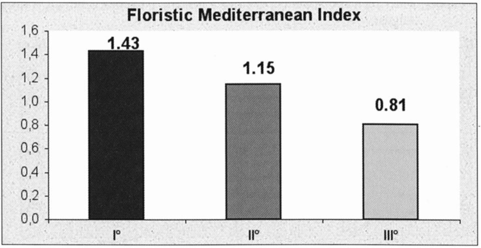

FIGURE 4 - Floristic Mediterranean Index exhibits differences among the three clusters.

Soils

Physical-Chemical analyses:

The results are shown in TABLE 2.

Texture and Organic Matter:

The profiles representative of each cluster (see scheme in FIGURE 7) are described as follows:

I° Cluster: the profile is characterized by high percentage of silt (46%) and clay (48%), the latter strongly increases from A to Bt horizon.

II° Cluster: the profile presents intermediate values of the three granulometric classes.

III° Cluster: the profile is characterized by high percentage of sand (74%) that decreases in the Bt horizon, where a large accumulation of clay (42%) occurs; this causes a temporary water retention, as displayed by hydromorphic features.

In all profiles organic matter is mainly concentrated in the A horizon. The pH values along the three clusters range from 5.9 to 6.8, identifying slightly acid to subacid soils, typical of this forest vegetation type (TABLE 2).

Soil water balance (FIGURE 5):

For each cluster it can be pointed out as follows:

I° cluster: water recharge (R) starts in early September and deficit (D) in August;

II° cluster: water recharge starts between October and November; deficit starts in August;

III° cluster: water recharge is achieved in late November; deficit starts in June.

In all profiles water reserve (S) is largely available throughout the winter and its utilisation (U) begins in April.

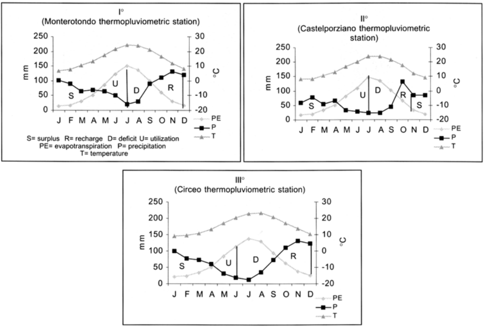

FIGURE 5 - Water balance according to Thornthwaite & Mather (1957) for each cluster.

Statistical treatments

The AWC data were continuous, normally distributed (*Anderson-Darling Normality* test = 0.499 P=0.195) and the variance within the data sets was homogeneous (*Levene's* test=1.087 P=0.351).

The output of the One-way Anova test (DF=2, SS=41018; F=6.35; P<0.05) for AWC allowed us to reject the null hypothesis that the three clusters have the same mean. To determine which cluster was different from which, the *Fisher LSD* test was carried out with an individual error rate with critical value at P<0.05. The Fisher test showed that the mean of cluster 3 was significantly lower than the mean of both clusters 1 and 2; specific analysis on these last two clusters showed that there was still a difference but not statistically significant (DF=1; SS=6510; F=1.88; P=0.184).

The output of Spearman rank-order correlation test showed positive correspondence between AWC and F: $r_S = 0.7$; $p<0.01$ (FIGURE 6).

The median of the soil profiles for AWC showed a moisture gradient decreasing from cluster 1 to 3 (TABLE 2, FIGURE 7).

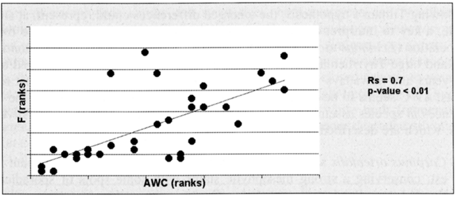

FIGURE 6 - Spearman rank-order correlation test between AWC and Ellenberg Soil Moisture.

Results demonstrate that:

1) The vegetation can be divided into three silvofacies (*Carpinus orientalis, Crataegus monogyna, Phillyrea latifolia*);
2) The silvofacies have different AWC values which identify a gradient from more mesic to more xeric silvofacies;
3) AWC could be a discriminant ecological factor in the species composition of the three silvofacies, remarking the different mesophily rate among them;
4) AWC values show a strong relationship with some of the flora based indicators (such as Ellenberg Soil Moisture and Floristic Mediterranean Index) (FIGURES 3, 6).

DISCUSSION

Soil available water capacity (AWC) may be a discriminant ecological factor in the species composition of the investigated forest. Ecological differences among the silvofacies emerged also from the analysis of Ellenberg classification and chorotypes. This study confirms, as found in the available literature data on this study types (Diekmann, 1995; Schaffers & Sykora, 2000; Pignatti *et al.*, 2001), the ability of Ellenberg indicators to detect environmental parameters. In particular, Soil Moisture (F) indicator can be a valid flora based tool to asses differences among plant communities. Furthermore, the relationship between soil

Nitrogen (N) and Light (L) indicators observed in the detected silvofacies, which have different evolution structure, confirms the "resource/ratio hypothesis of Tilman (1985). Mature communities are distinguished by moist and nutrient-rich soils and shady conditions; in the *Carpinus orientalis* silvofacies canopy is more closed, so that light interception by a larger phytomass increases (<L). On the contrary, when canopy is more open and the forest shows a tendency towards the shrublands in the edges and in some inner zones, light regime increases, affecting the amount of nutrients in the soils, as in the *Phillyrea latifolia* silvofacies. Following Tilman's hypothesis, the emerged differences could represent, at small scale, a key to interpret the ancient lowland forest, belonging to a single forest association (*Echinopo siculi-Quercetum frainetto)* which once covered a continuous and large Thyrrhenian subcostal belt until the XVIII century, destroyed over the years and nowadays reduced to few unconnected patches. In the forest remnants, AWC seems to be a significant discriminant factor responsible for the differences in species assemblage and for the different ecology of the three silvofacies, which are described below:

I° – *Carpinus orientalis* silvofacies, represents a good example of the ancient forest, conserving a strong mesophylic status with some spots of sporadically flooded woodland represented by *Carici remotae-Fraxinetum oxycarpae* (*Alnion glutinosae*). This is the most shady (<L) and temperate (<T) silvofacies, on moist and nutrient-rich soils (FIGURE 3), with higher species richness (TABLE IN APPENDIX) and prevalence of Eurasiatic flora (TABLE 1); soils are deep and evolved, with a high amount of clay and silt (FIGURE 7).

II° – *Crataegus monogyna* silvofacies, represents an intermediate condition, testified by high frequency of *Quercus robur* (39% *vs.* <15% in the other clusters). Soil water is still available for plants, but its seasonal recharge (R) is limited to a short period, as displayed by Thornthwaite hydrologic balance (FIGURE 5). Mesophylous edges with *Euonymus europaeus* and *Crataegus monogyna*, dynamically linked to *Q. cerris* and *Q. frainetto* woodlands (as in Bianco *et al.*, 2003), are included in this silvofacies.

III° – *Phillyrea latifolia* silvofacies, is distinguished by soil xerophily (<AWC, <F) and abundance of mediterranean chorotypes (FIGURE 4).The cluster corresponds to the most thermophylous and heliophylous (>T and >L) silvofacies of *Echinopo-Quercetum frainetto*, sometimes in contact with extrazonal forest remnants of *Quercus ilex* with a rather high frequency of *Q. pubescens.* Soils are shallow and scarcely developed. In this silvofacies the range of variability for Nitrogen is wider than in the other two silvofacies, mainly due to soil thickness (TABLE 2). The xerophylous silvofacies have shallower soils with higher organic matter contents and probably the limited depth of these profiles probably causes the organic matter to be concentrated in the surface layer rather than penetrating deeply into the soil. Another reason could be the slower decomposition rate of the sclerophyllous leaves, leading to a more consistent accumulation of organic matter.

In the first silvofacies the presence of patches periodically inundated and related to high AWC value, favours species occurring in hygrophylous woodlands (such as *Fraxinus oxycarpa, Alnus glutinosa, Carex remota*) and in temporary flooded depressions (*Polygonum hydropiper, Alisma plantago-aquatica*). In these wet conditions are found many *Fagetalia* species, such as *Acer obtusatum, Arisarum vulgare, Corylus avellana* and *Milium effusum* as well as the high frequency of nemoral geophytes as *Cyclamen repandum, C. hederifolium* and *Anemone apennina.*

The stands with lower AWC values are characterized by the presence and high frequency of xerophylous shrubs and small trees, both evergreen and broadleaved, including *Quercus pubescens, Phillyrea latifolia, Cercis siliquastrum, Fraxinus ornus, Erica scoparia, Myrtus communis, Acer monspessulanum, Juniperus oxycedrus.*

Along the resulting edaphic gradient, different community structure is recognizable, from more mature and complex communities with closed canopy to younger ones with tendency towards shrublands (FIGURE 7). High frequency of *Querco-Fagetea* species characterize the first two silvofacies, while high frequency of *Quercetea ilicis* species emerge in the less mature and more degraded silvofacies (TABLE IN APPENDIX).

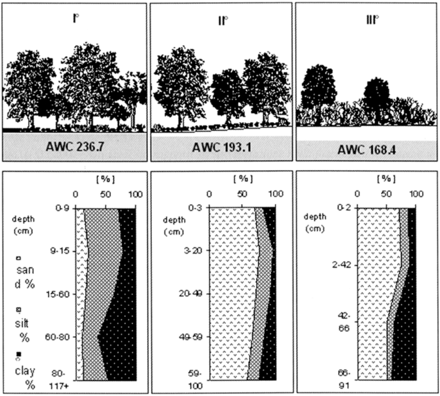

FIGURE 7 - Vegetation scheme showing the variations of the communities structure along the AWC gradient, decreasing from I° to III° cluster: The soil profile representative for each cluster shows the differences for texture and organic matter.

CONCLUSION

The results of this study point out that differences in Available Soil Water Capacity in the oak forest belonging to *Echinopo siculi-Quercetum frainetto* of Mediterranean area are associated with differences in environmental heterogeneity and species richness.

In the sampled areas, the rather high AWC value is probably the main factor allowing the sub-coastal oak-communities to survive during summer drought.

AWC is linked to the community structure and to the soil characteristics; the most evolved silvofacies is characterized by high soil water capacity, presence of wet spots, closed canopy and species richness.

Based on this study, AWC may be considered an environmental factor that maintains diversity in this forest type. Thus, it can be foreseen that in this climate water table overexploitation (associated to a progressive global warming), will cause in similar communities a shift towards slightly arid conditions, similar to cluster 3, with subsequent local vanishing of the most vulnerable meso-hygrophylous species and their substitution with xerophylous shrubs and small trees.

AWC measurements, as well as Ellenberg indicators have been proved to be very helpful to test small differences within the investigated silvofacies. Consequently, it is suggested to increase these quantitative/qualitative approaches in studies focused on the relationships between soils and plant communities, especially for conservation and management of forest ecosystems.

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RIASSUNTO

Il contenuto idrico del suolo rappresenta un fattore critico per la vegetazione forestale di ambienti mediterranei, specialmente in aree soggette ad un prolungato periodo di aridità estiva.

La quantità massima di acqua disponibile per le piante, nota come AWC (Available Water Capacity), rappresenta quella frazione che può essere assorbita dalle radici. Questa capacità idrica può svolgere un'efficace azione tampone sull'apparato radicale quando le precipitazioni sono scarse o del tutto assenti.

Sebbene la misura dell'AWC rappresenti un metodo standardizzato e largamente utilizzato, la letteratura specifica si riferisce prevalentemente a studi di carattere agricolturale, mentre le conoscenze sulle interazioni suolo-vegetazione sono ancora frammentarie.

Con questa indagine si è voluto testare se l'AWC potesse svolgere un ruolo di fattore discriminante per lo smistamento delle specie nei querceti caducifogli termofili riferibili all'associazione *Echinopo siculi-Quercetum frainetto* Blasi et Paura 1993 nomen inv., ordine *Quercetalia pubescentis* Br.-Bl. 1941.

Sono stati eseguiti 32 rilievi fitosociologici e altrettanti profili di suolo ad essi associati, in 5 differenti siti sottoposti ad un regime termo-pluviometrico similare. Dalle analisi pedologiche effettuate sui campioni di suolo sono stati calcolati i corrispondenti valori di AWC. La vegetazione è stata clas-

sificata applicando procedure di analisi statistica multivariata ai dati di presenza/assenza delle specie: è stato ottenuto un dendrogramma di tre cluster di rilievi, in base ai quali sono stati raggruppati i valori di AWC. Sono state quindi testate le differenze con ANOVA test (analisi della varianza) e l'output ha rivelato una differenza statisticamente significativa tra i tre gruppi ($F=6.35$; $P<0.05$).

Per approfondire le relazioni tra i pattern di vegetazione trovati e i fattori ambientali, sono stati utilizzati gli indicatori ecologici di Ellenberg e i corotipi.

I risultati hanno dimostrato che l'AWC può rappresentare un fattore discriminante per l'assemblaggio delle specie nei boschi esaminati; inoltre è correlato positivamente con l'indicatore di Umidità di Ellenberg.

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TABLE 1 - Chorotypes values in the three clusters.

	I°	II°	III°
Eurasiatic sensu latu	*53.1*	*46.6*	*38.6*
Boreal	*5.4*	*5.9*	*6.5*
Large distribution	*2.6*	*4.0*	*4.6*
Endemic	*0.5*	*0.4*	*0*
Eurymediterranean	*19.1*	*24.9*	*22.2*
Atlantic	*1.3*	*2.0*	*2.0*
Mediterraneanean-Montane	*0*	*0.4*	*0.7*
Stenomediterranean	*18.0*	*15.8*	*25.5*

TABLE 2 - Soils grouped according to the vegetation clusters:
the geologic substrate and the measured parameters are reported for each soil profile.
The median profiles in bold.

Sites	Discriminant species in *Quercus cerris* and *Quercus frainetto* woodlands	Soil classification	Rock	AWC	pH	Nitrogen	Organic C	Depth
	I° cluster			mm/1m		%	%	cm
1	*Alnus glutinosa* and *Fraxinus oxycarpa*	FLUVAQUENTIC ENDOAQUOLL	pleistocenic sands	226.7	7.2	0.2	5.9	154
2	*Quercus robur*	MOLLIC HAPLOXERALF	tuff	213.7	6.6	0.2	2.1	120+
3	*Quercus robur*	TYPIC EUTRUDEPT	limestone	193.2	7.3	0.2	2.5	120+
4	*Carpinus orientalis*	LITHIC HAPLOXEROLL	tuff	91.1	7.1	0.4	3.2	42
5	*Carpinus orientalis*	**ULTIC HAPLOXERALF**	tuff	**236.7**	**6.8**	**0.2**	**1.3**	**117+**
6	*Acer obtusatum*	ENTIC HAPLUDOLL	silty-clay sediments	243.0	8.5	0.3	2.7	145+
7	*Carpinus orientalis*	FLUVENTIC HAPLUDOLL	limestone	213.9	7.9	0.3	2.9	108+
8	*Carpinus orientalis*	ULTIC HAPLOXERALF	limestone	162.5	6.0	0.2	1.7	90+
9	*Carpinus orientalis*	MOLLIC HAPLUDALF	limestone	188.3	7.2	0.3	3.4	85+
10	*Carpinus orientalis*	TYPIC HAPLOXEREPT	limestone	126.3	6.7	0.3	2.4	60+
11	*Carpinus orientalis*	TYPIC HAPLOXEREPT	tuff	221.0	6.2	0.3	2.6	118+
12	*Carpinus orientalis*	ULTIC HAPLOXERALF	limestone	77.7	6.1	0.2	2.2	40+
	II° cluster			*St. Dev.*	*0.7*	*0.06*	*1.11*	
13	*Carpinus betulus*	AQUIC HAPLOXEREPT	pleistocenic sands	200.1	6.7	0.1	1.2	220
14	*Crataegus monogyna* and *Teucrium siculum*	TYPIC HAPLOXERALF	pleistocenic sands	172.4	6.1	0.2	1.9	100
15	*Crataegus monogyna*	MOLLIC HAPLOXEREPT	pleistocenic sands	169.0	6.2	0.1	0.6	200
16	*Quercus robur* and *Carpinus betulus*	ULTIC HAPLOXEROLL	pleistocenic sands	200.8	6.0	0.1	4.3	160
17	*Crataegus monogyna*	AQUULTIC HAPLOXERALF	pleistocenic sands	213.6	6.6	0.2	3.0	205
18	*Crataegus monogyna* and *Euonymus europaeus* Edges	AQUIC HAPLOXERALF	pleistocenic sands	180.7	7.0	0.1	1.4	110
19	*Crataegus monogyna*	LITHIC XEROPSAMMENT	pleistocenic sands	162.0	6.9	0.1	1.5	140
20	*Crataegus monogyna*	**MOLLIC HAPLOXERALF**	pleistocenic sands	**193.1**	**6.3**	**0.1**	**1.0**	**120+**
21	*Erica arborea*	TYPIC HAPLOXERALF	pleistocenic sands	192.8	6.4	0.1	0.7	200
22	*Quercus robur*	FLUVENTIC HAPLOXEROLL	tuff	238.0	7.2	0.3	2.5	150+
23	*Carpinus orientalis*	TYPIC EUTRUDEPT	limestone	199.8	8.0	0.2	1.9	180+
24	*Quercus robur* and *Crataegus monogyna*	PACHIC HAPLOXEROLL	tuff	193.7	7.1	0.2	1.6	160+
25	*Quercus robur*	TYPIC HAPLOXERALF	limestone	218.1	6.7	0.3	2.4	102+
	III° cluster			*St. Dev.*	*0.5*	*0.07*	*0.98*	
26	*Myrtus communis* and *Phillyrea latifolia* Edge	AQUULTIC HAPLOXERALF	pleistocenic sands	188.6	5.6	0.1	3.6	90
27	*Erica scoparia* and *Phillyrea latifolia* Edge	AQUULTIC HAPLOXERALF	pleistocenic sands	179.5	5.8	0.2	2.9	81
28	*Fraxinus ornus* and *Phillyrea latifolia*	**AQUULTIC HAPLOXERALF**	pleistocenic sands	**168.4**	**5.9**	**0.2**	**2.9**	**91**
29	*Phillyrea latifolia* and *Quercus frainetto* Edge	unclassified	pleistocenic sands	181.9	7.0	0.1	1.8	100
30	*Quercus pubescens*	LITHIC HAPLOXEROLL	limestone	67.9	7.8	0.7	6.5	75
31	*Quercus pubescens*	LITHIC HAPLOXERALF	limestone	110.8	7.1	0.6	6.2	44
32	*Quercus ilex* and *Quercus pubescens*	LITHIC HAPLOXEROLL	limestone	98.7	7.2	0.6	5.1	40
				St. Dev.	*0.8*	*0.23*	*1.69*	

Sites
Tre Cancelli: 1,13,15,16,18,19,26
Gattaceca: 2-12; 22-25;30-32
Padiglione: 14,17
Circeo: 27,28,29
Castelporziano: 8,20,21

TABLE IN APPENDIX - Table of the species/relevés ordered by classes of frequency.

	I° cluster	II° cluster	III° cluster
Querco-Fagetea species	Classes of frequency		
Quercus cerris	V	V	IV
Hedera helix	V	IV	II
Euonymus europaeus	IV	IV	III
Acer campestre	IV	III	I
Anemone apennina	IV	I	I
Carpinus orientalis	IV	I	-
Crataegus oxyacantha	IV	II	-
Cornus mas	III	II	-
Sorbus torminalis	III	-	-
Malus sylvestris	III	-	-
Crataegus monogyna	II	IV	II
Quercus frainetto	II	III	III
Brachypodium sylvaticum	II	II	II
Ajuga reptans	II	I	II
Euphorbia amygdaloides	II	II	I
Viola reichenbachiana	II	II	I
Stachys officinalis	II	I	III
Melica uniflora	II	I	I
Tamus communis	II	I	-
Melittis melissophyllum	II	-	-
Quercus robur	I	II	I
Acer obtusatum	I	-	-
Quercetea ilicis species			
Phillyrea latifolia	I	II	V
Asparagus acutifolius	IV	I	V
Smilax aspera	III	II	IV
Rubia peregrina	IV	I	IV
Carex distachya	-	I	III
Pistacia terebinthus	-	-	III
Myrtus communis	-	I	II
Quercus ilex	I	I	I
Juniperus oxycedrus	-	-	I
Chamaerops humilis pl.	-	-	I
Arbutus unedo	-	II	-
Sedum cepaea	-	II	-
Erica arborea	-	I	-
Other species			
Fraxinus ornus	V	I	V
Lonicera caprifolium	V		II
Ruscus aculeatus	IV	V	V
Ligustrum vulgare	IV	III	IV
Rubus ulmifolius	IV	II	III
Rosa sempervirens	IV	II	I
Cyclamen hederifolium	IV	I	-
Arum italicum	III	III	II
Aristolochya rotunda	III	II	I
Cyclamen repandum	III	II	-
Ulmus minor	III	II	-
Prunus spinosa	III	I	II
Lathyrus venetus	III	I	-
Styrax officinalis	III	-	II
Anchusa italica	III	-	-
Carex flacca	II	I	II
Oenanthe pimpinelloides	II	I	II
Sorbus domestica	II	-	II
Aspienium onopteris	I	-	-
Cornus sanguinea	II	-	-
Ranunculus velutinus	II	-	-
Lonicera etrusca	I	II	III
Allium triquetrum	I	II	II
Cruciata glabra	I	II	I
Alliaria petiolata	I	I	-
Galium aparine	I	I	-
Pulicaria odora	I	I	II
Carpinus betulus	I	I	
Rosa canina	I	I	I
Buglossoides purpureo-caeruleum	I	I	
Glechoma hederacea	I	I	-
Luzula forsteri	I	I	-
Mespilus germanica	I	I	-
Ostrya carpinifolia	I	I	-
Pyrus pyraster	I	I	-
Ranunculus lanuginosus	I	I	-
Rumex sanguineus	I	I	-
Sambucus nigra	I	I	-
Stachys sylvatica	I	I	-
Symphitum bulbosum	I	I	-
Symphitum officinale	I	I	-
Quercus pubescens	I	-	III
Ornithogalum pyramidale	I	-	II
Holcus lanatus	I	-	I
Polypodium vulgare	I	-	I
Viburnum tinus	I	-	I
Alisma plantago-aquatica	I	-	-
Alnus glutinosa	I	-	-
Arisarum vulgare	I	-	-
Bellis perennis	I	-	-
Bryonia dioica		-	-
Callitriche stagnalis	I	-	-
Carex divulsa	I	-	-
Carex remota	I	-	-
Clematis vitalba	I	-	-
Corylus avellana	I	-	-
Dactylis glomerata	I	-	-
Echinops siculus	I	-	-
Fallopia convolvulus	I	-	-
Fraxinus oxycarpa	I	-	-
Genista tinctoria	I	-	-
Lathyrus clymenum	I	-	-
Lathyrus pratensis	I	-	-
Laurus nobilis	I	-	-
Lysimachia vulgaris	I	-	-
Lysimachia nummularia	I	-	-
Mentha aquatica	I	-	-
Millium effusum	I	-	-
Myosotis caespitosa	I	-	-
Onopordum illyricum	I	-	-
Platanthera bifolia	I	-	-
Polygonum hydropiper	I	-	-
Rumex obtusifolius	I	-	-
Solanum dulcamara	I	-	-
Sparganium erectum	I	-	-
Stachys salvifolia	I	-	-
Anagallis arvensis	-	II	-
Anthoxantum odoratum	-	II	-
Asphodelus aestivus	-	II	-
Pteridium aquilinum	-	II	-
Viola suavis	-	II	-
Hypericum perforatum	-	I	I
Ranunculus sardous	-	I	I
Rubus caesius	-	I	I
Carex hallerana	-	I	-
Centaurium erythraea	-	I	-
Crepis neglecta	-	I	-
Cynosurus polybracteatus	-	I	-
Daphne gnidium	-	I	-
Euphorbia exigua	-	I	-
Euphorbia peplus	-	I	-
Festuca heterophylla	-	I	-
Fragaria viridis	-	I	-
Galium divaricatum	-	I	-
Gastridium ventricosum	-	I	-
Gaudinia fragilis	-	I	-
Geum urbanum	-	I	-
Hypericum australe	-	I	-
Juncus effusus	-	I	-
Juncus gr. bufonius	-	I	-
Lathyrus apaca	-	I	-
Linum tryginum	-	I	-
Lotus ornithopodioides	-	I	-
Mentha pulegium	-	I	-
Petrorhagia prolifera	-	I	-
Phleum pratense	-	I	-
Pinus pinea	-	I	-
Psilurus incurvus	-	I	-
Sanguisorba minor	-	I	-
Scutellaria columnae	-	I	-
Stachys ocymastrum	-	I	-
Stellaria pallida	-	I	-
Teucrium siculum	-	I	-
Thalictrum aquilegifolium	-	I	-
Viola alba	-	I	-
Cercis siliquastrum	-	-	III
Cistus salvifolius	-	-	II
Erica scoparia	-	-	II
Acer monspessulanum	-	-	I
Aegilops ovata	-	-	I
Aethorrhiza bulbosa	-	-	I
Anthemis arvensis	-	-	I
Brachypodium rupestre	-	-	I
Briza maxima	-	-	I
Briza media	-	-	I
Cynosurus echinatus	-	-	I
Danthonia decumbens	-	-	I
Daucus carota	-	-	I
Juniperus communis	-	-	I
Lavatera punctata	-	-	I
Linum bienne	-	-	I
Luzula multiflora	-	-	I
Melica ciliata	-	-	I
Onobrychis viciifolia	-	-	I
Plantago lanceolata	-	-	I
Pyrus amygdaliformis	-	-	I
Scabiosa maritima	-	-	I
Taraxacum officinale	-	-	I
Trifolium campestre	-	-	I
Typha latifolia	-	-	I