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Syntaxonomy and synecology of thermophilous Mediterranean pines *Pinus halepensis* Mill. and *P. brutia* Ten. in Greece

P. Konstantinidis¹, P. Xofis² and G. Tsiourlis³

^{1,3} National Agricultural Research Foundation, Forest Research Institute, 57006 Vassilika - Thessaloniki, Greece.

² Technological Education Institute, Department of Landscape Architecture, 66100 Drama, Greece

¹ Corresponding author E-mail: pavkon@fri.gr

ABSTRACT

Pinus halepensis Mill. and *Pinus brutia* Ten. are among the most important constituents of forests vegetation around the Mediterranean basin. This paper presents a syntaxonomic overview of *P. halepensis* and *P. brutia* dominated vegetation formation in the Mediterranean zone of Greece (*Quercetalia ilicis*), based on the classification of 162 relevés from 21 (8 continental and 14 insular) mountainous areas throughout Greece. Three associations and seven sub-associations are described and presented in a synoptic constancy table. *Pistacio-Pinetum halepensis* De Marco, Veri, Caneva 1984 is the most widespread and is found in the entire continental Greece and most islands. It is further subdivided into two sub-associations. *Junipero phoeniceae-Pinetum brutiae* Akman, Kurt, Demiryurek, Quezel, Kurt, Evren and Kucukoduk 1993, on the other hand, is geographically confined on the eastern parts of Greece. It is further sub-divided into five sub-associations. *Rhamno lycioidis-Pinetum brutiae* nova is found only in Crete and it is further subdivided into three sub-associations. The sub-associations are reflecting primarily local peculiarities in the disturbance regime and the influence of local floristic elements.

Key words: Aleppo pine, calabrian pine, phytosociology, *Quercetalia ilicis*, vegetation classification.

AIMS AND BACKGROUND

Pinus halepensis Mill. and *Pinus brutia* Ten. are among the commonest species of the Mediterranean basin. They are found across the entire Mediterranean region: *P. halepensis* in the west part and *P. brutia* in the east, accounting for more than 25% of the forested area in North Africa and about 50% in Mediterranean Anatolia, forming a major economic and ecological asset, not only in these regions, but also in southern France, eastern Spain and Greece¹. The forests of *P. halepensis* and *P. brutia* are considered as ultimately ecosystems (climax)². Both species are perfectly adapted to the specific characteristics of Mediterranean climate and soil environment. They are photophilous, frugal and xerothermic species and resistant to high temperatures. The two species have similar requirements in terms of soil properties and geomorphological characteristics. *Pinus halepensis* occurs mainly on marly limestone and marls but also widely on compact fissured limestone soils and on *terra rossa* soils. *P. brutia* is also found on marly limestones and especially fissured soils (such as in Crete) but grows also on compact limestone. Moreover, peridotites, dolerites, serpentines and gabbros,

which are almost absent from the western Mediterranean, are a favourable habitat for *P. brutia* (e.g. Cyprus³). They grow also in arid, dry and shallow soils and they exhibit high resilience to frequent fires. They have the ability to colonize disturbed areas and abandoned lands⁴.

In Greece, the two species usually occur at low altitudes up to 600m (occupying the area of *Quercetea ilicis*), although *P. brutia* reaches 1200 m in the south slopes of Crete⁵. Despite their similar ecological behaviour, the two species do not ever co-exist and they never create mixed stands. The “frontier” is an imaginary line drawn between the island of Thasos and peninsula of Athos that reaches the western part of Crete.

Only few studies refer to the synecology and syntaxonomy of *P. halepensis* and *P. brutia* forest in Greece (e.g. 1, 3, 4). The aim of the current study is to present a systematic classification of *P. halepensis* and *P. brutia* dominated Mediterranean forests of the *Quercetea ilicis* vegetation zone, which is its natural distribution area, throughout Greece, and to attempt to identify the ecological parameters affecting their distribution. The prevalence of *P. halepensis* and *P. brutia* dominated plant communities in the Eastern Mediterranean landscape is reciprocal to the scarce syntaxonomic knowledge about these vegetation types. In this respect, the vegetation data provided by this study are generally worth being communicated to the scientific community.

EXPERIMENTAL

Phytosociological data across continental and insular Greece were collected on representative areas, which represent a variety of environmental conditions covering almost the entire country. The study area includes 21 sites across Greece. Eight sites across continental Greece: Evros and Sithonia, (Northern Greece), Parnitha (Central Greece), Telethrio and Kandyli (Eastern Greece), Helmos and Kyllini (Southern Greece) and Foloji (Western Greece). One site across Ionian Sea: Zakynthos. Five sites across Aegean Sea: Lesbos (Northern Aegean), Kerkis, Ampelos and Chios (Central Aegean), Rodos and Karpathos (Southern Aegean). And six sites across Crete: Asterousia, Dikti-Lasithi, Giouchtas, Lefka Ori, Dikti-Omalos, and Thryptis.

The climate of the *Quercetea ilicis* vegetation zone is typical Mediterranean with mild and rainy winters, warm and dry summers, and an extended period of sunshine throughout the year. However, the climatic conditions vary from the semi-dry conditions of Attica, Crete, and Eastern Greece to the relatively sub-humid to humid conditions of Northern and Western Greece. A common characteristic of all the above areas is their mountainous character and their sharp relief, independently of their size. The geologic structure is quite similar in most sites, where a calcareous substratum is dominant with parts of recently formed sea sediments (mostly in islands), while other geological formations are only occasionally met. The dominant soil type in the islands is *terra rossa* followed by rendzina and alluvial soils.

From 2000 to 2009, 162 relevés were collected during May and June using the Braun-Blanquet⁶ approach. The following parameters were recorded for each relevé in homogeneous plots of 300 m²: elevation, inclination, exposition, and species abundance for each vegetation layer. The identification of vegetation units was done using the polythetic-divisive method TWINSpan⁷. The original Braun-Blanquet scale of abundance was converted into an ordinal scale⁸, with values ranging from 1 to 7 corresponding to the original 7 classes of abundance. A data matrix was then created including all samples and species with the converted abundance values. The pseudospecies cut levels used were 0.1, 3.1, 4.1, 5.1, and 6.1. ordinal scale units.

Classification in 5 levels was performed and the minimum number of samples to justify further division was set at 5. The maximum number of indicator pseudospecies was set at 7 and all pseudospecies were available as indicator species. The initial classification resulted in a large number of groups but not all of them represented distinctive vegetation units, so some of the groups were merged at higher division levels. This process was aided by the results of a Detrended Correspondence Analysis ordination (DCA)⁹. After construction of a synoptic table, the table was reordered into a diagnostic table clearly showing the differences between the plant communities. This table was used for the identification of diagnostic species and for denomination of the different plant communities. The nomenclature of the plant communities was typified with the International Code of Phytosociological Nomenclature (ICPN)¹⁰. However, referred syntaxa names before 2002 are literally cited and not obligatory in accordance with ICPN.

RESULTS AND DISCUSSION

Based on TWINSpan and DCA results, seven distinctive vegetation units were identified and, following the Braun-Blanquet approach, were classified under three associations and seven sub-associations. Table 1 shows the frequencies of the diagnostic species for the corresponding vegetation units. According to these results, the syntaxonomic synopsis of the *P. halepensis* and *P. brutia* forests in Greece is:

Quercetalia ilicis Braun-Blanquet 1947

Quercetalia ilicis Braun-Blanquet 1947

Quercion ilicis Braun-Blanquet 1934 em. Rivas-Martínez 1975

1. *Pistacio-Pinetum halepensis* De Marco, Veri, Caneva 1984

1.1 *Pistacio-Pinetum halepensis typicum*

1.2 *Pistacio-Pinetum halepensis anthylletosum hermaniae*

Oleo-Ceratonion Br.-Bl. 1936 em. R.M. 1974

2. *Junipero phoeniceae-Pinetum brutiae* Akman, Kurt, Demiryurek, Quezel, Kurt, Evren and Kucukoduk 1993.

2.1 *Junipero phoeniceae-Pinetum brutiae fraxinetosum ornus*

2.2 *Junipero phoeniceae-Pinetum brutiae crucianelletosum latifolia*

2.3 *Junipero phoeniceae-Pinetum brutiae rubietosum tenuifolia*

3. *Rhamno lycioidis-Pinetum brutiae nova*

3.1 *Rhamno lycioidis-Pinetum brutiae phlomidetosum lanatae*

3.2 *Rhamno lycioidis-Pinetum brutiae Lamyropsisetosum cynaroides*

1. Association: *Pistacio-Pinetum halepensis*

The association is present in both continental and insular Greece on areas characterised by subhumid Mediterranean climate and subject to frequent fires. Substrates on those areas are mainly limestone with several areas on flysch and schist and less often granites. The shrub cover reaches 70%, and the understorey is relatively scarce (20%). The soils vary from relatively deep and productive to shallow and infertile while slopes are generally steep and often very steep. The characteristic species forming this association are general considered among the most tolerant, in terms of soil aridity, species of the Mediterranean. The first description of the association was made by De Marco et al.¹¹ in Italy. *Pistacio-Pinetum halepensis* is widespread around the Adriatic coasts¹². Although many authors classify the association in the alliance *Oleo-Ceratonion siliqua*¹³, our relevés clearly indicate that the Aleppo pine forests that belong to this association share the floristic attributes of the alliance *Quercion ilicis*.

1.1 Sub-association: *Pistacio-Pinetum halepensis typicum*

This is the typical form of the association and it appears throughout the Mediterranean region of the country (Sithonia, Telethrio, Parnitha, Kandyli, Helmos, Kyllin, Foloi, Samos (Kerkis and Ampelos), Zakynthos) apart from the eastern part of northern Greece. This sub-association extends from the sea level to the upper altitudinal zones of the *P. halepensis* distribution, where it is succeeded by oak and fir forests, forming occasionally complex mixed stands. Most of the characteristic species are not affected by the varying levels of soil acidity although in some cases appear species that can grow in very alkaline soil.

1.2 Sub-association: *Pistacio-Pinetum halepensis anthylletosum hermaniae*

This sub-association occurs sporadically in very dry and hot slopes, in the *Oleo ceratonion* zone (Sithonia, Telethrio, Parnitha). Soils are rocky but well-drained. The typical species are xerophytes, some of which photophile with low water requirements.

2. Association: *Junipero phoeniceae-Pinetum brutiae*

This association has been found in the eastern part of Greece: Rhodos, Karpathos, Lesvos, and Samos in the Aegean Sea and Evros prefecture in Northern Greece. The characteristic species of the association are known to thrive on dry and well-drained habitats. This association has been described first by Akman *et al.*¹⁴ in the province of Mugla (southwestern Turkey) close to the Aegean islands included in the current study. A similar association, the *Junipero phoeniceae-Pinetum halepensis*, is described in areas of the Western Mediterranean¹⁵.

2.1 Sub-association: *Junipero phoeniceae-Pinetum brutiae fraxinetosum ornus*

This sub-association is found on the cooler areas of the distribution of *P. brutia*, in the fringe between *Quercetea ilicis* and *Quercetalia pubescentis*, in the eastern part of Greece (forest of Dadia (Evros) and Ampelos Mountain (island of Samos)). The floristic composition of the association has affinities to both *Oleo-Ceratonion* and *Quercion ilicis* alliances, while many species that mostly found on deciduous oak stands are present in this sub-association.

2.2 Sub-association: *Junipero phoeniceae-Pinetum brutiae crucianelletosum latifolia*

This sub-association has been found only in the island of Lesvos. The characteristic species are frugal. Due to its proximity to Turkey, it is enriched with floristic elements from Minor Asia¹⁶. Moreover, its distribution in relatively higher altitude than the typical Mediterranean zone, leads to the absence of characteristic shrubs and climbing species of *Quercion ilicis*.

2.3 Sub-association: *Junipero phoeniceae-Pinetum brutiae rubietosum tenuifolia*

This sub-association is mainly found on the islands of Eastern Aegean and on soils originating from hard limestone. It is floristically quite rich with many accompanying species. It is a quite open vegetation type allowing the establishment of a big number of accompanying and resilient to disturbance species.

3. Association: *Rhamno lycioidis-Pinetum brutiae nova*

This association was identified only in Crete. The island is characterized by a typical Mediterranean climate along a gradient of precipitations from West (sub-humid) to East (semi-dry) and from the level of the sea to the top of the three main mountainous massives. The geological structure of Crete is quite homogenous with limestone geological substrates dominating, while flysch have also an important distribution. The characteristic species is *Rhamnus lycioides* subsp. *oleoides* (*R. graecus*). The association is characterized by the abundance of phrygantic species. The community consists of shrubs with an open canopy of *pinus*, growing on initial or eroded soils.

3.1 Sub-association: *Rhamno lycioidis-Pinetum brutiae phlomidetosum lanatae*

This sub-association is considered as the more xerothermic expression of the association and is mainly distributed in the Eastern and Central parts of Crete. It has a dense understorey consisting mainly of phryganic disturbance tolerant species. Limestone geological substrates dominate, while flysch have also an important distribution. The soils are terra rossa rendzines and alluvial and mainly alkaline and eroded by overgrazing and frequent wildfires.

3.2 Sub-association: *Rhamno lycioidis-Pinetum brutiae Lamyropsisetosum cynaroides*

This sub-association is characterized by the present of *Lamyropsis cynaroides* that is included in the IUCN Red Data List¹⁷ in the category of threatened plants characterized as rare. The sub-association is found in Lefka Ori in wettest parts of Crete, with average annual precipitation between 1900 and 2000 mm. The geological substrate is a rugged marble and dolomite massif, rich in rock debris and karstic formations.

CONCLUSIONS

The current study indicates the close floristic affinities between *P. halepensis* and *P. brutia* dominated forests at the higher taxonomic levels of classe and order. On the other hand at the levels of alliances and lower there are pronounced floristic differences with many elements of *Pistacio-Pinetum halepensis* being absent from *Rhamno lycioidis-Pinetum brutiae* and only occasionally found on *Junipero phoeniceae-Pinetum brutiae*. Both, species composition and the DCA results indicate that *Pistacio-Pinetum halepensis* is confined on the cooler and drier areas of the *P. halepensis* distribution range. Based on the geographical distribution of the three association one would expect that *Junipero phoeniceae-Pinetum brutiae* would represent an ecotone between the two other association. However, the DCA results indicate that *Junipero phoeniceae-Pinetum brutiae* is an association with unique characteristics and a distribution on the drier areas of the distribution zone of thermophilous pines in Greece. The DCA results further indicate that, *Rhamno lycioidis-Pinetum brutiae* is present on the warmer and drier areas of thermophilous pines distribution zone, which occurs on the eastern parts of Crete. Further the ecological and geographical isolation of Crete could explain the presence of local indigenous and rare species in this association.

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