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Investigation of the establishment and dynamics of black pine in the fir zone of Tymphristos mountain under climate change

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Abstract The establishment and dynamics of black pine in comparison to fir on the Tymphristos mountain, Greece, was investigated based on their growth behavior and the ecological factors governing the area. Specifically, from a black pine stand, derived from reforestations and which presently contains also fir individuals, tree-ring cores were obtained up to the pith from both species. Subsequently, the tree-rings width was measured, followed by the analysis of radial growth in relation to site conditions and vegetation zone. The results show the incapacity of black pine to compete fir due to the local bioclimatic conditions which partly explains the absence of the species in the area. However, this condition may be altered by the transition to a drier bioclimatic type due to the evolution of climate change.

Keywords: dendroecology, forest ecology, tree-rings, reforestations, climate change

1. Introduction

Reforestations with black pine is a common practice applied in recent decades in the mountainous areas of Greece, especially within the fir zone. Among the reasons governing this choice lie the fast and without specific requirements development of the species, soughing to protect soils from erosion but also the creation of a precursor forest that will support the natural regeneration and growth of fir forests after forest fires. This practice has particular importance as the problem of forest fires in the coniferous zone has been growing in the recent years due to climate change (Arianoutsou et al. 2008). Black pine naturally grows throughout mainland Greece from 400 to 2000 m altitude (Korakis 2015), but is absent in some mountainous areas such as the Tymphistos mountain where it exists only through reforestations. The absence of natural distribution of the species in the area was the motivation of this research, which aims to investigate the possible competition of black pine in relation to fir, as well as the investigation of the site factors of the area. Additionally, the future projection of the species' dynamics in the region is investigated, in view of the evolving climate change.

2. Materials and Method

The study area is located on the borders of the prefectures of Fthiotida - Evritania (38º53-51´´ latitude, 21º52-56´´ longitude and 1239 m above sea level). Twenty (20) tree ring cores were obtained from a stand of black pine (derived from reforestation) and fir trees (native), from a total of 10 trees of each species (Katsaiti 2021). After sample preparation, dating and counting of tree-rings widths (Stokes and Smiley 1968, Fritts 1976), 20 time series of the tree-ring withs were obtained of each species. The examination of the area's site factors was performed based on available literature data of the area's forests. The bioclimatic analysis was done using climatic data of the period 1973-2019 derived from the Ag. Nikolaos meteorological station (38º53´20´´ B, 21º52´07´´ A, altitude 1120 m) of the Institute of Mediterranean Forest Ecosystems and Forest Products Technology, located close to and at a similar altitude of the study area.

3. Results - Discussion

The measurement and dating of the tree-rings at breast height, revealed that black pine trees were 53 years old (1966-2018) and fir 52 years old (1967-2018), which shows that fir established naturally immediately after the black pine reforestation. Mean tree-ring width of black pine was 3.09 mm whereas that of fir was larger and at 3.88 mm. The comparison of the average tree-rings width curves of both species showed that black pine tree-rings width for the first 10 years was higher than that of fir, but then it significantly decreased (Fig. 1). The average tree-rings' width for the first 10 years were statistically different ($p<0.01$) and was 7.92 for *Pinus nigra* and 5.55 for *Abies cephalonica*. Similarly, the average tree-rings' width (mmx100) for the period 1993-2018 was statistically different ($p<0.01$) and was 1.58 for *Pinus nigra* and 3.08 for *Abies cephalonica*.

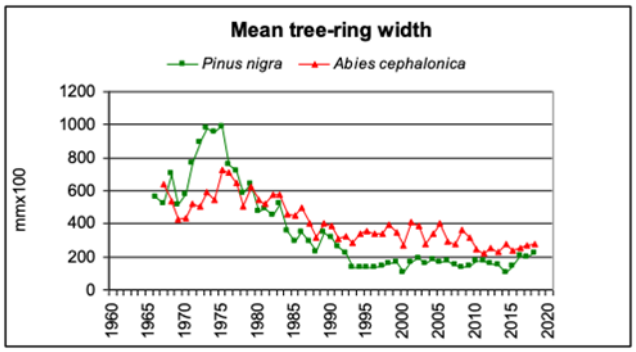

Figure 1. Average tree-rings width curves of black pine and Cephalonian fir

This advantageous fir tree-ring width increase in comparison to that of black pine, is indicative of the competitiveness of the species, and therefore indicative that this species will prevail in the area. The limestone soil and rock that dominate the area as well as the topographic conditions are favorable for both species' growth (Quezel 1979; Quezel and Barbero 1985; Ducrey and Oswald 1990). Furthermore, the area's vegetation zone is that of oro-mediterranean zone which is

also favorable for both species' distribution. On the contrary, the bioclimatic conditions are more favorable for fir rather than for black pine. Based on the *Emberger* bioclimatic diagram and the extent occupied by the black pine and the Cefalonian fir (Quezel 1974; Quezel and Barbero 1985), it appears that the black pine is outside its bioclimatic distribution limit for the study area (Fig. 2). This is mainly due to the very high precipitations, as expressed by the high value of the *Emberger* pluviometric quotient (Q2) and less than the minimum temperature as expressed by the average minimum temperature of the coldest month (m).

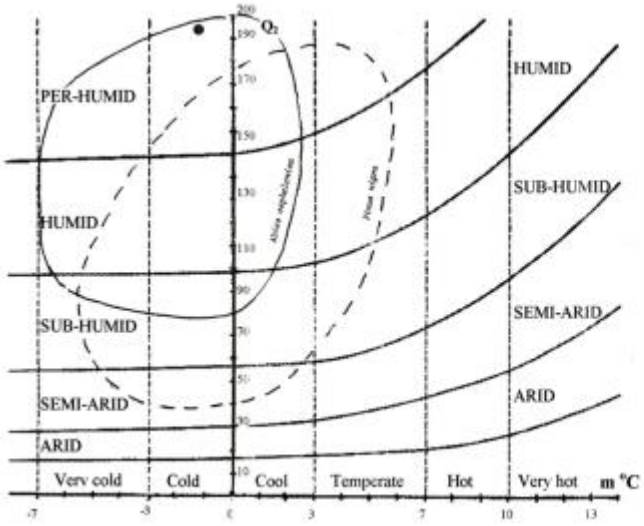

Figure 2. Schematic diagram of the distribution of black pine (dashed line) and Cefalonian fir (solid line) on Emberger bioclimatic diagram and position (black point) of the Ag. Nikolaos meteorological station

Based on the above, it appears that the causing factor for the absence of black pine by natural distribution in the study area can be attributed to fir competition which, as a shade tolerant species with a dynamic increase in humid bioclimates, dominates and does not allow the black pine to grow and regenerate.

However, if climate change scenarios for Greece are verified (Bank of Greece 2011) where a decrease in rainfall and an increase in temperature is predicted, the black pine, present from previous reforestations, is expected to naturally extend into the fir forests of the region as it may respond better to drier and warmer bioclimates (Fig. 2).

Of course, this, within the framework of this research, is not yet evident in the area but, on the contrary, it seems that the existing reforestations with black pine are suppressed by fir which tends to extend its natural distribution in them. An indication of fir retreat could be that of fir decline and necrosis that has become increasingly common in the past few years (Papadopoulos et al. 2007). However, similar phenomena of intense insect infestations and significant damage from snowstorms due to extreme weather phenomena are observed more frequently recently in the black pine reforestation of the area. It is therefore understood that forest adaptation and mitigation to climate change is not a simple problem and that it requires proper management.

4. Conclusions

Black pine's distribution and dynamics is confined to the mountain and oro-mediterranean zone and the per-humid bioclimatic type due to the strong competition posed by fir. However, it is a species that could establish naturally in this zone in the future, under the evolution of climate change. For this reason, it is and will continue to be a key species for reforestation projects in the mountainous zone of Greece.

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