

Original article

Tree-ring patterns and climate response of Mediterranean fir populations in Central Greece



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ABSTRACT

Central Greece is the distribution common area of the endemic fir species *Abies cephalonica* and *Abies borisii-regis*. Forests fires and fir decline are some of the problems both species encountered during the past decades, with these problems being exacerbated lately by climate change. The present research investigates tree-ring patterns and climate responses of three fir populations along a latitudinal gradient in Central Greece. All three populations were homogeneous in their dendrometric, silvicultural and site characteristics but were phenotypically different. The analysis of tree-ring widths site chronologies revealed that 59% of their variability interprets common tree-ring patterns whereas another 25% interprets their differences as they appear from a south to north direction. This variability in tree-ring widths is proportional to the variability observed for precipitation, temperature and drought from a south to north direction in this region. The tree-ring to climate relationships revealed that the main climatic factor affecting fir tree-ring width is late spring and summer precipitation to which is positively correlated. Also, tree-ring widths were positively affected by the temperatures of the October and April before the growing season. However, June drought adversely affected tree-ring widths of the northern site while it positively affected them at the beginning of the spring season, especially for the southern site and in September for the northern sites. All dendrochronological statistics, tree-ring patterns and climate-growth relationships show a south to north trend following the climatic and phenotypic (species) variation observed to the same direction for fir populations in Central Greece.

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1. Introduction

Climate studies foreseen a significant global warming trend for the 21st century in the Mediterranean basin associated with a decrease in precipitation, especially in the warm season, and an increase in the frequency and severity of drought and other extreme events (Räisänen et al., 2004; IPCC, 2007; Giorgi and Lionello, 2008; Lelieveld et al., 2012). This climate change will impact the growth, productivity and present distribution of Mediterranean vegetation (De Dios et al., 2007; IPCC, 2007). A report on the environmental, economic and social impacts of climate change in Greece (Bank of Greece, 2011), estimates a spatial redistribution of Greek forests and a forest cover reduction due to climate change by 2100 if no additional measures are taken under the currently applied management strategy. Specifically and based to the same report, the foreseen temperature increase and precipitation decrease will result in the expansion of heat tolerant forest species by 2–4%, shrinkage of cold tolerant forest species by 4–8% and desertification

expansion by 1–2%, depending on the climate change scenario (A2: +3.1 °C and –35 mm of precipitation or B2 = 4.8 °C and –84 mm of precipitation).

Such changes involve fir forests as well. Dendroecological studies showed that increasing climate warming and exceptional drought periods played a major role in the growth, distribution and health of fir forest across Europe (Bert et al., 1990; Aussenac, 2002; Camarero et al., 2003). During the last decades there were cases reporting weakening or necrosis of Mediterranean fir forests in Greece, attributed primarily to the drought-related extreme periods and high spring or low winter temperatures (Markalas, 1992; Brofas and Economidou, 1994; Tsopelas et al., 2004; Papadopoulos et al., 2007). Fir forests decline, noticeable mainly in southern and central Greece, is one of the earliest signs of climate change impact on Greek forest ecosystems (Bank of Greece, 2011). Forest fires occurrence at higher altitudes is increased lately in number and destruction, associated with the summer high temperatures and drought (Arianoutsou et al., 2010; Giannakopoulos et al., 2011; Sarris et al., 2013; Koutsias et al., 2012, 2013). Many of these fires involved fir forests such as the devastating fires of 2007 in the Parnitha and Taygetos mountains. These pressures are expected to

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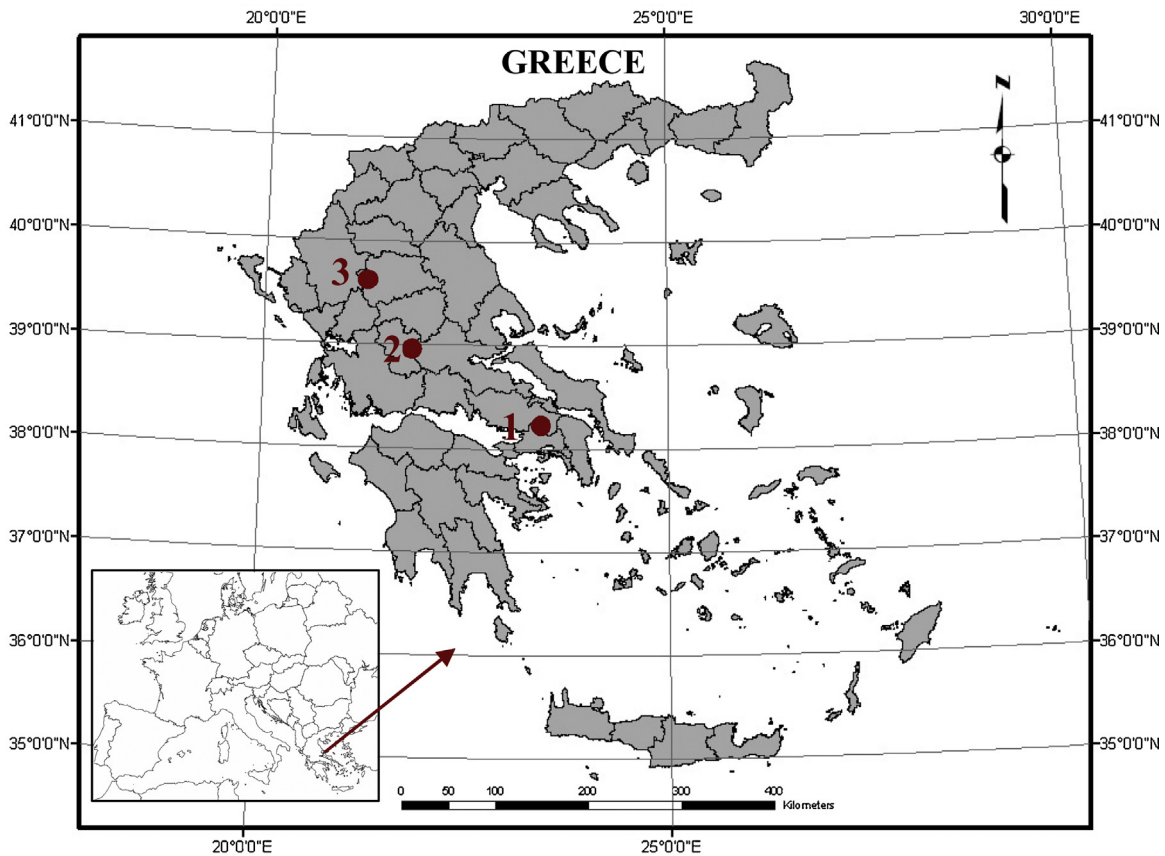


Fig. 1. Location of the study sites (1: PARN, 2: KARP, 3: PERT).

affect the future expansion and growth of Mediterranean fir forests in Greece.

There are three fir species in Greece, *Abies alba* Miller, restricted to the northern border of the country and the Mediterranean fir species *Abies cephalonica* Loundon and *Abies borisii-regis* Mattf. (Strid and Tan, 1997). *A. cephalonica* is an endemic Greek species expanding mainly in southern and central Greece while *A. borisii-regis*, an endemic of the southern Balkan Peninsula, disperses mainly in the northern and central part of the country (Athanasiadis, 1986). Their present distribution is the result of the genus paleogeography and the species adaptation to the local conditions. *A. cephalonica* occurred after the Pliocene (Linares, 2011), while the hybrid *A. borisii-regis* evolved from the southern migration of *A. alba* during the glaciation period and its contact with *A. cephalonica* (Fady and Conkle, 1993; Scaltsoyiannes et al., 1999; Linares, 2011). The area of the central Greece from 38°N to 40°N latitude constitutes a common distribution region of *A. cephalonica* and *A. borisii-regis* where both species are present in high frequency (Athanasiadis, 1986; Strid and Tan, 1997). A distinction based on the morphological characteristics of the two fir species is often difficult due to intermediate morphological features which, therefore, often require a genetically based differentiation. *A. cephalonica* is more drought resistant and less demanding than *A. borisii-regis*. *A. cephalonica* appears in the sub-humid and humid bioclimatic layer, mainly in compact limestone - dolomitic rocks, whereas *A. borisii-regis* occurs in the humid bioclimatic layer and out of the Mediterranean climate (European type) and into less compact rocks mainly of flysch (Barbero and Quezel, 1976; Quezel, 1979).

The Mediterranean firs are the most representative tree species at high altitudes in Central Greece. Previous studies carried out for *A. cephalonica* investigated tree-ring width relations with precipitation and temperature on a local scale (Papadopoulos et al.,

2007; Papadopoulos, 2009; Koutavas, 2013) as well as with CO₂ increase (Koutavas, 2008, 2013; Frank et al., 2009). Two Greek site chronologies of *A. cephalonica* and *A. borisii-regis*, retrieved from the International Tree Ring Data Bank (NOAA, 2015), have also been used in broader dendroclimatological studies of the Mediterranean area (Nicault et al., 2008; Touchan et al., 2014; Trouet, 2014). The present research advances from the previous studies in Greece as it concerns a wider area and takes into account the geographical variability of the climate as well as the phenotypic diversity of the fir forests in the area. Specifically, the objectives of this study were (a) to analyze tree-ring width growth patterns of Mediterranean fir populations along a latitudinal gradient and among phenotypically different populations in Central Greece, (b) to quantify the inter-annual variability of tree-ring width and to relate this with climate (precipitation and temperature) variability and (c) to investigate tree-ring to climate relationships for the above mentioned populations.

2. Materials and methods

2.1. Study sites

Three sampling sites with natural fir forests were selected in the central continental Greece, in the eastern part of Pindos mountain range (rain shadow), within an altitudinal zone from 1100 to 1300 m. a.s.l, from a south to north direction. Specifically, the following sites were chosen: a fir south population of Mount Parnitha (PARN) which is identified as *A. cephalonica*, a north population of the Pertouli area (PERT) which is identified as *A. borisii-regis* and a population in the intermediate region of Karpenissi (KARP) where fir presents ambiguous characteristics between the two species (Fig. 1). In Greece, and particularly in Central Greece, fir pop-

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