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The Urgency of Implementing Field Research for Fir Forest Conservation and Management: Case Studies in Central Greece †

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Abstract: Findings from monitoring Greek fir forests in central Greece regarding radial growth, insect infestations, plant communities, and climate response have highlighted the urgent need for expanded field research to address critical conservation challenges within the fir forest ecosystem on Giona and Parnassus mountains. This underscores the urgency of adopting measures to mitigate the impacts of both abiotic and biotic factors. Our findings so far, encompassing biometric data, tree ring analysis, observations on plant communities, climatic response, and insect infestations—primarily *Choristoneura murinana* (European Bud Moth)—across various stands on the mountain, have revealed significant local infestations of varying degrees. In many instances, these infestations were detected in adult trees, particularly in sunny areas or near country roads. Furthermore, our research has revealed the varied ability of the fir trees to adapt to both minor and significant climatic variations. The proposed research aims to monitor, preserve, and protect the fir trees, utilizing new knowledge for informed decision-making in their management. The project's scope includes studying the growth characteristics of the fir forest, mitigating threats from biological factors (primarily the moth *Choristoneura murinana*-Lepidoptera, Tortricidae) by involving pheromones and other biological methods, promoting natural regeneration, preserving biodiversity, and evaluating the water status of the fir trees in response to climate change. Investigating their interactions and understanding the ecosystem's status concerning the previously mentioned aspects is a significant priority for biological and genetic diversity, landscape aesthetics, recreation, and sustainable regional development (with economic impacts on local beekeepers and guesthouse owners). The evaluation of the implementation of the National Biodiversity Strategy in Greece has shown partial or minimal progress in addressing new threats and challenges, as well as in promoting new approaches. The proposed project, with specific actions, aligns with the spirit of the National Biodiversity Strategy and contributes to the strategy goals within the framework of conservation, restoration, and the strengthening of nationwide enhancement actions.

Keywords: forest management; tree growth; biotic factors; *Choristoneura murinana*; climate; Greece

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1. Introduction

Over the last decades, severe drought events, characterized by high temperatures and low precipitation, have caused intense forest dieback episodes across Europe [1,2]. In addition, Mediterranean regions might become most vulnerable to tree species loss, mainly due to the increased frequency and intensity of drought events [3,4]. The forest ecosystems of Southern Europe, during the last century, have been subject to direct abiotic disturbances, e.g., droughts and other climatic factors, e.g., [5–8]. In Greece, water scarcity is probably one of the main climatic constraints limiting forest growth. Studies have presented a robust correlation between available water and tree ring width and tree growth in different Mediterranean forests and for different tree species, e.g., [7–14]. Forest ecosystems are unique in having a detailed description of historical events and disturbances imprinted in

the tree-ring record. Fire is the most important disturbance, and it is found that fire-scarred trees have this event depicted in their tree rings. The climate is another factor that leaves an imprint on the tree-ring record. Defoliation events are often found in the studies of the time series of tree-ring widths, and they are separated from drought-induced events by simultaneously studying non-host tree-ring widths of major defoliators

The urgency of implementing field research for fir forest conservation and management is evident, especially as Mediterranean forest ecosystems face new challenges due to rising temperatures during the growing season. Ecosystems that fail to evolve relevant adaptations will likely disappear, e.g., [15,16].

2. Methods

In previously mentioned studies, significant emphasis was placed on methodologies involving the use of drought indices alongside measurements of average tree ring width (Figure 1) and the development of a common nonlinear function for determining a suitable tree growth model over time, along with correlations between these factors. In this work, the index SPI is used since it operates at various scales, separates hydrological drought from environmental drought, and operates in situations where there is no temperature data. However, the reduction in radial growth is obscured within the obtained time series, and to uncover the most critical factors, advanced bio-mathematical and/or physico-chemical techniques are also required. These include time series analysis using multivariate singular spectral analysis and examining the amount of carbon-13 (^{13}C) in the α-cellulose of tree rings, which can differentiate the effect of light and water availability that cause oscillations and variations in tree ring width patterns [17–19]. Implementing this approach alongside the previously mentioned methods may lead to more validated results.

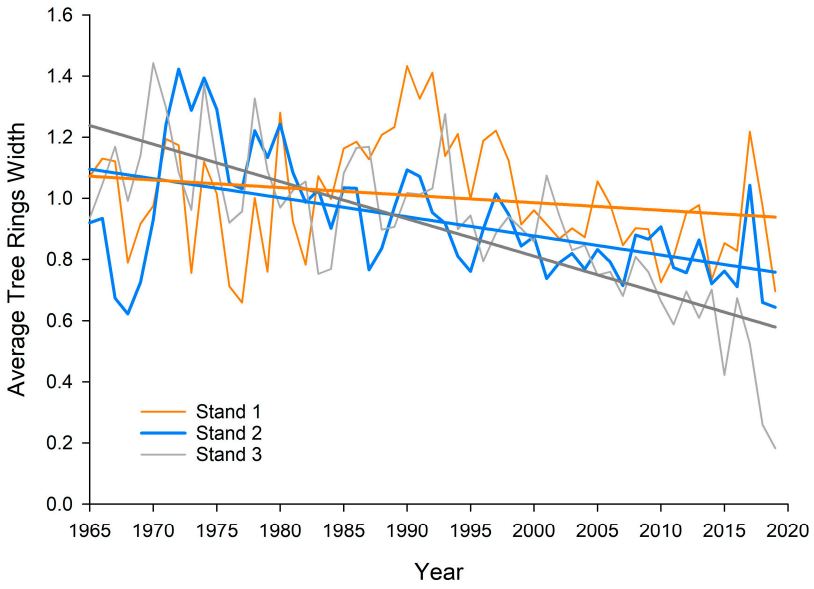

Figure 1. Master average tree-ring width indices for three stands at different elevations 988 m (S1), 1.274 m (S2), and 1.257 m (S3)] in Mt. Giona over time [12].

3. Results and Discussion

Species-specific sensitivity to warmer or drier climates could affect tree growth behavior directly. The predicted increase in the severity and frequency of drought events, e.g., [15,16] globally, might have major impacts on tree growth, e.g., [2]. Previous work [12] revealed a reduced growth index for two different altitude stands regarding fir plots on Mt. Giona after 1999, indicating unfavorable growth conditions over the last two decades. The reduced average ring width index (ARWI), according to the standard precipitation index (SPI), is collateral to those two decades of mild or moderate precipitation conditions, wet or dry. One extreme drought event and one extreme wet event were investigated over a period

of 55 years. Those extreme events were translated to negative or positive changes in growth. Other milder events were slightly imprinted on the measurable tree ring growth. The average maximum temperature during the growing season and in specific months (April, July, and August) was linked to tree growth for Mt. Giona stands. Evapotranspiration during this period inversely affected fir growth. One of the stands showed a pronounced decline in tree ring growth (ARWI < 0.6), especially in recent years [12].

A decline in growth was observed by our team after 1998 for two elevations in Mt. Giona, not connected with SPI but seemingly associated with observed defoliations of the insect *Choristoneura murinana* (Lepidoptera, Tortricidae) or European Fir Budworm (EFB). Finally, our 5 years of research revealed and confirmed that EFB causes sporadically severe defoliation to Greek fir at Mt. Giona and Mt. Parnassus (Photo 1), and the relation between climate and tree ring width is disturbed because of the EFB attack at Mt. Giona. Our findings so far, encompassing biometric data, tree ring analysis, observations on plant communities, climatic response, and insect infestations—primarily EFB—across various stands on the mountains, have revealed significant local infestations of varying degrees. In many cases, these infestations have been found in mature trees, especially in sunny areas near country roads or beekeeping facilities. Feedback from beekeepers indicates that these infestations are reducing honey production (Figure 2). Furthermore, our research revealed the varied ability of the fir trees to adapt to both minor and significant climatic variations.

Figure 2. EFB infestations close to beekeepers' facilities (Photo credit: Panagiotis P. Koulelis).

The monitoring of Greek fir forests in central Greece shows the need for immediate research in the Giona and Parnassus mountains, focusing on radial growth, insect infestations, and climate impacts. Urgent action is needed to address both abiotic and biotic threats. The proposed research aims to monitor, preserve, and protect the fir trees, utilizing new knowledge for informed decision-making in their management. The project's scope includes studying the growth characteristics of the fir forest, mitigating threats from biological factors (primarily EFB) by involving pheromones and other biological methods, promoting natural regeneration, preserving biodiversity, and evaluating the water status of the fir trees in response to climate change. Investigating their interactions and understanding the ecosystem's status concerning the previously mentioned aspects seems to be a significant research priority.

4. Conclusions

A comprehensive understanding of tree growth across various sites, species, climates, and management practices is vital for foresters and stakeholders. The proposed project, specifically focused on the Greek fir, aligns with the National Biodiversity Strategy and

supports its goals within the framework of conservation, restoration, and strengthening nationwide enhancement efforts.

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