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PLANT BIODIVERSITY DYNAMICS IN THE FIR UNDERSTORY (*Abies cephalonica* Loudon) OF MOUNT KIRPHI, GREECE: CURENT STATUS AND FOREST MANAGEMENT PERSPECTIVE

SUMMARY

Mediterranean Greek fir forests depend on the understory plant diversity to achieve ecological balance, recycle nutrients, and conserve biodiversity. The present study examines understory plant diversity regarding species richness, cover, and density in two selected Greek fir (*Abies cephalonica*) forest stands of Mount Kirphi in Greece. Twelve species belonging to 11 genera and 7 families were noted, including the commonly found *Poaceae* and *Fabaceae.* Stand 2, had greater species richness (12 species) than stand 1 (10 species); however, none of the differences observed regarding plant density and cover were statistically significant. The majority of the plants showed a preference for bright light and moderate soil moisture, as these conditions allow the understory plants to experience different environmental changes, according to the indicator values. The occurrence of Mediterranean, European, and Southwest Asian species highlights the biogeographical importance of the studied forest ecosystem. The forest of Mount Kirphi is vital for the local ecosystem, biodiversity, nitrogen cycling, and habitat support. Dominated by *Poaceae* and *Fabaceae*, the biodiversity within ensures ecological stability, with species richness, density, and coverage suggesting the understory will likely maintain stability despite any future environmental disturbances. The presence of native species across different fir stands emphasizes the need to protect Mediterranean firs, as their adaptability to changes in natural and anthropogenic factors highlights the need for low-impact, biodiversity-focused forest management and the importance of continuous monitoring within regulatory frameworks. Predictive models based on climate projections will serve to aid in the conservation of Greek fir forests.

Keywords: Understory vegetation, diversity, ecology, indicators, Greek fir.

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INTRODUCTION

Greece is a significant hotspot of Mediterranean biodiversity, distinguished by several indigenous plant species and unique plant ecosystems (Blondel and Aronson, 1995; Dimopoulos *et al*., 2013, Solomou *et al*., 2023). The understory flora is tightly linked to the surrounding forest ecosystem, necessitating an understanding of the establishment of forest plants and their ecological role within the environment. This study is part of an extensive analysis comparing flora in the Greek fir (*Abies cephalonica*) forest on Mount Kirphi of Greece. Greek fir (*Abies cephalonica*), along with oak, beech, pine, and spruce, is not only of major economic importance in Greece but also holds significant ecological value (Koulelis *et al.*, 2022; Samaras *et al.,* 2015). As Strid and Tan (1997) point out, fir is widely distributed across the country, forming the backbone of many mountainous forest ecosystems. Forest inventory data clearly reflect its importance—Greek fir is one of the country's most economically valuable tree species. Its forests contribute approximately 43 million cubic meters of tradeable industrial roundwood, representing over 30% of Greece's total timber production (Ministry of Agriculture, 1992). Beyond its commercial value, Greek fir supports biodiversity by providing habitat for numerous plant and animal species and contributes to vital ecosystem services such as carbon sequestration, soil stabilization, and water regulation.

In light of the above, the importance of the fir understory is vital for ecological balance and nutrient cycling and provides habitat and a stimulant for various invertebrate and vertebrate species (Gilliam, 2007).

Due to their complex interactions with forest surroundings, these understory plant communities serve as an excellent model for clarifying the mechanisms of adaptation and adaptive strategies related to the ecological functions of various plant species within forest ecosystems (Gilliam, 2007).

This study focuses exclusively on evaluating the understory plant biodiversity in Greek fir ecosystems by assessing species richness, average density, and coverage, emphasizing their contribution to ecosystem resilience.

MATERIAL AND METHODS

Mountain Kirphi is situated in Greece, north of the bay of Antikyra, within the Gulf of Corinth and the region of Viotia (Fig. 1,2,3). The area is mainly composed of limestone rocks, with Greek fir forests dominating the northern slopes, while the lower areas are covered by scrub vegetation. The two study sites, Stand 1 and Stand 2, are situated north of the settlement of Arachova, at elevations of 777 meters and 800 meters, respectively. The planned closeness of these stands encourages the upkeep of consistent microclimatic conditions, accommodates similar disturbances or environmental events, and allows for a broader sampling of tree species within the mountainous landscape. In the two forest stands, herbaceous plant species were sampled.

Sampling occurred during the peak growing season in late spring (May–June), when the majority of herbaceous species were identifiable. In each forest stand, 18 quadrats of 1 m² were systematically positioned along parallel transects at regular intervals to ensure spatial representativeness and reduce sample bias. In each quadrat, all herbaceous plant species were recorded and the individual counts per species were enumerated.

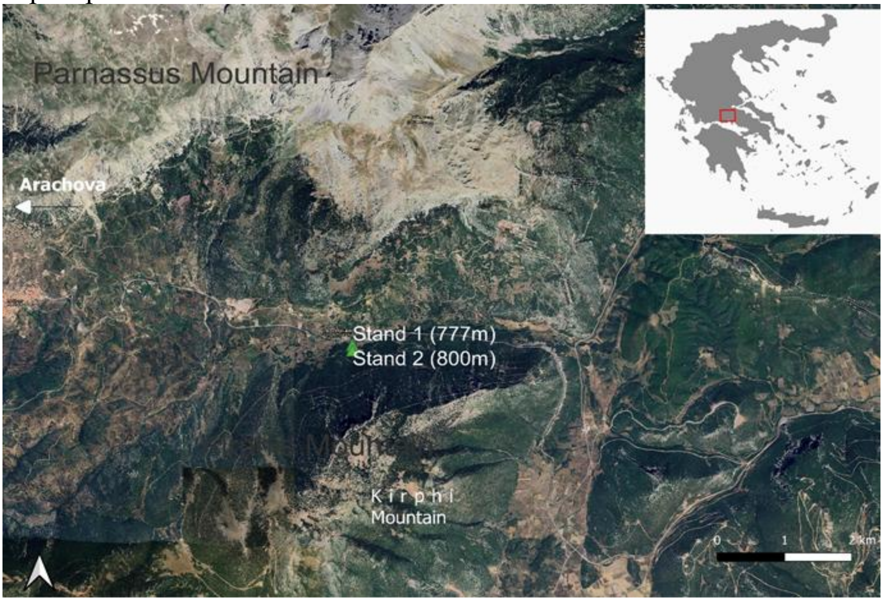


Figure 1. Location of the study areas in Central Greece: Stand 1 (38.4747° N, 22.6431° E) and Stand 2 (38.473972° N, 22.643194° E).

Figure 2. Mount Kirphi's northern aspect (photo by Dr. Panagiotis Koulelis, 2023).

The overall plant cover was visually assessed as a proportion of the quadrat area. Representative samples, including vegetative and reproductive components when available, were collected and subsequently identified in the laboratory for species that could not be recognized in situ. We used Flora Europaea (Tutin *et al.*, 1968; Tutin *et al*., 1993), Flora Hellenica (Strid and Tan, 2002), and Vascular Plants of Greece: An Annotated Checklist (Dimopoulos *et al*., 2013) to sort the plant specimens. We employed Ellenberg indicators (Ellenberg *et al*., 1992) to evaluate the ecological preferences of understory species, specifically concerning light and moisture, to enhance our understanding of the relationship between mountain flora and the growth and survival strategies of conifer species at the study sites.

Figure 3. *Abies cephalonica* in Mount Kirphi (photo by Dr. Alexandra Solomou, 2021).

RESULTS AND DISCUSSION

Understory vegetation composition, density and cover

In the studied area, 12 plant species belonging to 11 genera and 7 families were identified (Table 3). The most numerous families were *Poaceae* and *Fabaceae* (Fig. 4). Stand 2 had the highest number of plant species (12 species), while stand 1 had the fewest (10 species). In addition, 100% of plant species are native/non-range restricted in both Stands. European–Southwest Asian, Mediterranean, Mediterranean-European, and Mediterranean–Southwest Asian species were well represented in two stands. Based on the life form spectrum of the vegetation, therophytes contributed the most species to the study area, followed by hemicryptophytes (Fig. 5). Figures 6 and 7 show the mean herbaceous plant density (individuals/m^2) and cover (%) on stands 1 and 2. There was no statistically significant difference in the mean plant density ($F = 0.86$, $p = 0.36$) and plant cover (%) ($F=0.02$, $p=0.88$) between the two stands, indicating that the vegetation structure was similar across both stands.

Table 3. Plant species in Stand 1 and 2.

Plant species	Family	Stand 1	Stand 2
Aegilops neglecta Bertol.	*Poaceae*	+	+
Crucianella angustifolia L.	*Rubiaceae*	+	+
Echium plantagineum L.	*Boraginaceae*	+	+
Galium murale (L.) All.	*Rubiaceae*	+	+
Medicago lupulina L.	*Fabaceae*	+	+
Melica ciliata L.	*Poaceae*	+	+
Poa bulbosa L.	*Poaceae*	+	+
Reseda lutea L.	*Resedaceae*		+
Sedum hispanicum L.	*Crassulaceae*		+
Trifolium angustifolium L.	*Fabaceae*	+	+
Trifolium stellatum L.	*Fabaceae*	+	+
Viola reichenbachiana Boreau	*Violaceae*	+	+
Total		10	12

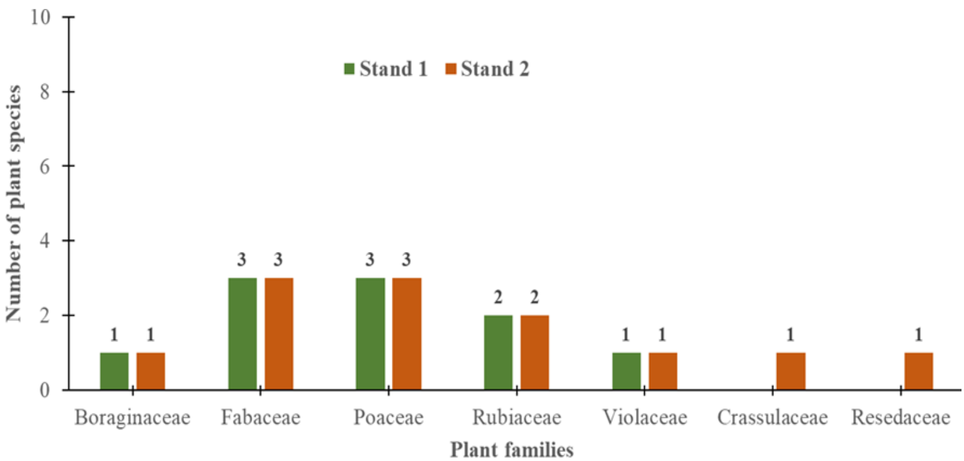
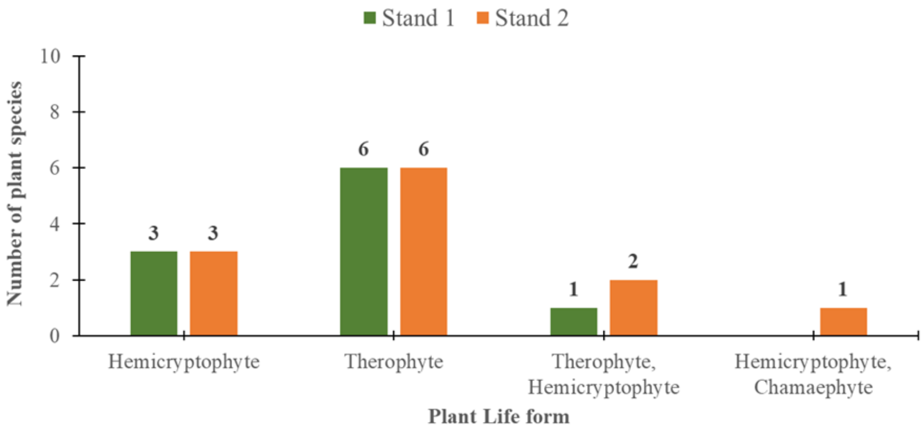


Figure 4. Distribution of plant species across families in the investigated stands.

Table 4. Number of plant species Chorology in the stands.

	Stand 1	Stand 2
Circumtemperate	1	1
European-SW Asian	2	3
Mediterranean	2	2
Mediterranean-European	2	2
Mediterranean-SW Asian	2	2
Paleotemperate	1	2

Figure 5. Plant Life Form in Stands 1 and 2



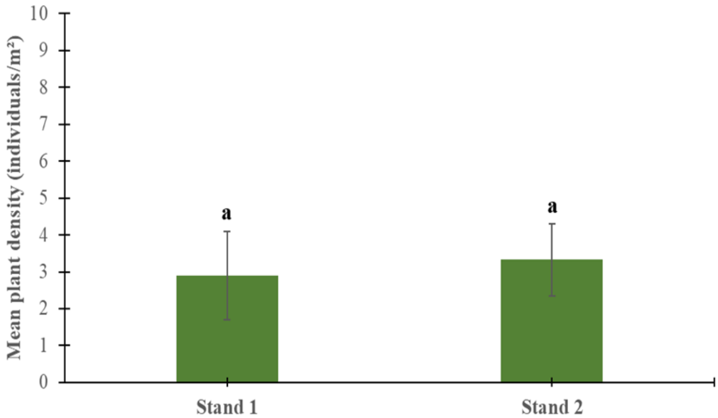


Figure 6. Mean density (individuals/m^2) of herbaceous plants in stands 1 and 2. For all stands with the same letter, the difference between the means is not statistically significant.

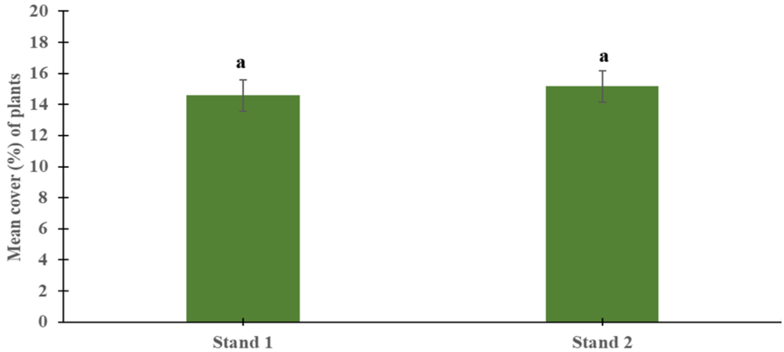


Figure 7. Mean cover (%) of herbaceous plants in stands 1 and 2. For all stands with the same letter, the difference between the means is not statistically significant.

Table 5. Ellenberg-type indicator values for plant species in Stand 1 (S.1) and 2 (S.2). Ecological indicators selected are in order: light (L), soil moisture (F), and Temperature (T).

	*Light		**Moisture		***Temperature	
Plant species	**S.1**	**S.2**	**S.1**	**S.2**	**S.1**	**S.2**
Aegilops neglecta Bertol.	7	7	5	5	9	9
Crucianella angustifolia L.	7	7	4	4	X	x
Echium plantagineum L.	8	8	4	4	9	9
Galium murale (L.) All.	7	7	NA	NA	X	x
Medicago lupulina L.	7	7	5	5	X	x
Melica ciliata L.	7	7	NA	NA	X	x
Poa bulbosa L.		8		4		x
Reseda lutea L.		7		3		9
Sedum hispanicum L.	8	8		3	9	9
Trifolium angustifolium L.	7	7	6	6	X	x
Trifolium stellatum L.	7	7	4	4	9	9
Viola reichenbachiana Boreau	4	4	NA	NA	NA	NA

* **Light**: Our classification system is precise, with 5 indicating a semi-shade plant, 7 representing a half-light plant, and 8 denoting a light plant.

****Moisture**: Plants show remarkable adaptability, with 3 indicating a plant that can survive in missing damp soil, 4 representing a plant that can transition between values 3 and 5, and 5 indicating plants that thrive in fresh soils.

******Temperature:** 9 refers to plant species that prefer warm environments and mean annual temperature around 20°C or more, and X refers to plants with a wide ecological range.

The Ellenberg indicator values are widely used to express plants' ecological preferences. These values are commonly used for bioindication, which involves making assumptions about the environment based on the species composition of a particular community's vegetation patterns. Table 5 presents the Ellenberg indicator values for the plant species of the two stands (Values for Greece were obtained from Tichý *et al.*, 2023). These values provide insights into the ecological preferences of the species in terms of light, moisture and temperature, helping to better understand the environmental conditions that influence their distribution and growth in the study sites.

Forest Management Perspective

To our knowledge, the selected areas are not subject to intensive forest management. Even though, effective forest management in Greek fir (*Abies cephalonica*) ecosystems, such as those on Mount Kirphi, must integrate understory biodiversity as a core component of ecological health and resilience. The study's findings indicate that these forests maintain functional biodiversity even under varying environmental conditions. This ecological stability—largely due to native species from the *Poaceae* and *Fabaceae* families and their adaptability to light and soil moisture conditions—highlights the need for low-impact, biodiversity-focused forest management. Maintaining light availability through selective thinning and avoiding excessive canopy closure are key strategies. Since these native species thrive in bright, moderately moist environments, it is also essential to limit the use of heavy machinery, control grazing pressure, and prevent the spread of invasive plants.

An intriguing theory supporting the idea that plant species are crucial indicators of forest ecosystem health suggests that a single keystone species or a functional group can maintain specific ecosystem functions, highlighting the importance of biodiversity (Swift *et al.*, 2004). Stand 2 showed slightly greater species richness than Stand 1, but both areas demonstrated comparable ecological characteristics regarding plant density and cover. The prevalence of native species and diverse ecological origins highlights the importance of these stands within their respective ecosystems, emphasizing their contribution to regional biodiversity and ecological stability.

Our study found that the most numerous families in the two stands are *Poaceae* and *Fabaceae.* This revelation underscores the current ecological landscape in Greece, as both families rank among the top three in terms of prevalence in Greece and the Mediterranean (Blondel and Aronson, 1995; Dimopoulos *et al.*, 2013; Maxted and Bennett, 2001). According to Gilliam (2007), the understory as a major component of forests–plays a crucial role in energy flow, nutrient cycling, biodiversity, and regenerative capacity. Recognizing that the understory rapidly adapts to both natural and human-induced disturbances, which helps prevent erosion and promotes the development of other species (Lencinas *et al.*, 2011; Simonson *et al.*, 2014; Tinya and Ódor, 2016), highlights the ecological importance of these strata. The understory populations now appear to reflect a diverse and resilient ecological base that is most able to tolerate disturbance and continue to provide valuable ecosystem services into the future. In summary, the analysis in Table 5 is compatible with Ellenberg's biodiversity indicator suggesting that the biodiversity of the fir's understory plants is typical for this habitat type. This underscores the ecological stability of the understory, which plays a crucial role in maintaining the overall health and resilience of the local Greek fir ecosystem. For the optimal growth of species with index values of 8 like *Echium plantagineum, Poa bulbosa,* and *Sedum hispanicum L.*, sunlight is needed. Species with an index value of 7 for shade tolerance, adapt well to brightly lit areas but can also survive light partial shading. Furthermore, one species (*Viola reichenbachiana*) was shared in both stands, with an index value of 4, indicating the species' preference for semi-shade under a tree or shrub canopy or in dappled shade or receiving subjective sunlight (Middleton *et al.,* 2015). Overall, there appears to be sufficient light penetrating the fir understory in this area. We primarily observed young fir trees with relatively small canopies, which may be linked to this finding. Both stands are also dominated by moisture-dependent plants, particularly in terms of moisture availability.

Specifically, we observed four species common to both communities with index value 4 (a species occurring in a dry and fresh stand type), suggesting the possibility of these species being adaptable to soil moisture and transitioning between conditions as implied by the index. Two other species in Stand 2 (with an index value of 3), identified in the present study, can survive in dry conditions (*Reseda lutea* L., *Sedum hispanicum* L.), indicating that these plants are also present in slightly damper soils. Moreover, one-half of the plants belong to the nine-temperature index class, which is related to an environment with a relatively mild climate characterized by mean annual temperatures of approximately 20 degrees Celsius. These plants indicate a climate with plenty of light and typically high but varying moisture. These optimum climate conditions can increase growth rates by prolonging the growing season. The founded customized combination of plants can support improvements in soil structure, assist with nutrient availability, and regulate moisture, which altogether creates the ideal environment for trees to grow.

Plants are essential to forest ecosystems, promoting ecological balance, biodiversity, and resilience. They serve as primary producers, converting solar energy into organic matter through photosynthesis and thus forming the basis of the food web (Chapin *et al.* 2011). Understory plant root systems enhance soil stability and combat erosion, particularly among pioneering and ground cover species like *Aegilops neglecta* and *Sedum hispanicum* (Pérez-Harguindeguy *et al.*, 2013). Nitrogen-fixing plants, including *Medicago lupulina* and *Trifolium angustifolium*, improve soil fertility, allowing other organism’s access to nutrients (van der Heijden *et al.*, 2008). Numerous flowering plants, like the observed *Echium plantagineum* and *Viola reichenbachiana*, are crucial for pollinators, providing nectar and pollen for bees, butterflies, and other insects (Potts *et al.*, 2016).

Additionally, shade-tolerant understory plants help maintain microclimates by retaining moisture and moderating temperature fluctuations (De Frenne *et al*., 2013). Some plants, like *Poa bulbosa*, are resistant to grazing and trampling, which benefits herbivore populations and preserves habitat structure (Cingolani *et al*., 2005). A diverse range of plant species, such as the ones we found, strengthens the stability and resilience of ecosystems, enabling forests to rebound from disturbances such as fires, droughts, and human activities (Loreau & de Mazancourt, 2013). Acknowledging and safeguarding the crucial roles of understory plants is vital for advancing forest conservation, tackling climate change, and preserving ecosystem services.

CONCLUSIONS

The forest~~s~~ of Mount Kirphi is essential for the local ecosystem, biodiversity, nitrogen cycling, and habitat support. The Poaceae and Fabaceae groups are the most dominant and diversity underpins ecological stability. Observations on species richness, density, and coverage indicate that the understory will likely maintain stability despite any potential environmental disturbance~~s~~ within the forest floor layers. The Ellenberg indicator values clarify the ecological needs and adaptations of the observed species regarding light, moisture, and temperature. Despite some of the differences across fir stands, the presence of specific native species in both types highlights the imperative to protect Mediterranean firs. This species class can easily adjust to different plant growth patterns, making these plant communities flexible to changes in both natural and anthropogenic factors. periodic monitoring of understory richness, density, and cover can guide adaptive responses. By prioritizing conservation of native understory flora and promoting continuous ecological monitoring, forest management plans can enhance nutrient cycling, habitat complexity, and resistance to future climatic and/or anthropogenic pressures.

Consequently, further long-term research is necessary to improve understanding of the impacts of changing climatic conditions on understory plant species in the fir forests across the country in the future. Thus, analyzing the impact of canopy structure on light accessibility and understory development may provide significant insights into forest succession and resilience. Investigating soil properties and soil-biota interactions, along with plant biodiversity, may clarify the ecological underpinnings of understory stability.

Current findings establish a foundation for employing remote sensing techniques alongside field investigations, which may enhance and specify the species distribution models essential for formulating efficient conservation policies. Mediterranean fir forests have received relatively little scientific attention, and multi-site research could enhance the ecological framework for adaptive management, helping to protect and manage these ecosystems from environmental changes.

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