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Exploring Biodiversity and Disturbances in the of Peri-Urban Forests of Thessaloniki, Greece

Lydia-Maria Petaloudi *, Petros Ganatsas * and Marianthi Tsakaldimi

Laboratory of Silviculture, Department of Forestry and Natural Environment, Aristotle University of Thessaloniki, P.O. Box 262, GR54124 Thessaloniki, Greece; marian@for.auth.gr
* Correspondence: petalydi@gmail.com (L.-M.P.); pgana@for.auth.gr (P.G.)

Abstract: Forests host important plant biodiversity. Nevertheless, due to climate change and human disturbances, the floristic quality of forest ecosystems is degraded. Greek peri-urban forests biodiversity is threatened by anthropogenic activities such as forest fragmentation, pollution, garbage, etc. Measurement of biodiversity status and the floristic quality assessment can be used to estimate the degree of forest degradation caused by anthropogenic disturbances. In this study, we compared and evaluated six forest ecosystem types in the peri-urban forests of Thessaloniki, northern Greece, by using Shannon's biodiversity index as well as and α and β diversity Sørensen indices. Furthermore, we recorded the prevailing anthropogenic disturbances and compared the plant families and the ruderal species appearing in each forest ecosystem. Finally, the average conservatism value (C value) of the plant species found in each ecosystem was determined in order to calculate the ecosystem floristic quality index. Analysis of the results showed that the floristic and ecological parameters tested greatly vary among ecosystems. Broadleaf forests of higher altitude hosted the greatest biodiversity, and the higher floristic quality index and plant conservation value. On the contrary, most disturbances and most ruderal species were recorded in ecosystems of lower altitude, adjacent to the city (*Pinus brutia* forest and Maqui vegetation), the least disturbed ecosystems were found in the steep slopes (Castanea sativa forest). Most ruderal species found belonged to the *Asteraceae* and *Rosaceae* families. Accessibility and attractiveness of stands were positively correlated with disturbances. Insufficient management, lack of protection measures, and littering removal contribute to the increase in the level of disturbance.

Keywords: α and β biodiversity; Hortiatis mountain; Shannon index; ruderal species; floristic quality index

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Citation: Petaloudi, L.-M.; Ganatsas, P.; Tsakaldimi, M. Exploring Biodiversity and Disturbances in the of Peri-Urban Forests of Thessaloniki, Greece. *Sustainability* **2022**, *14*, 8497. https://doi.org/10.3390/su14148497

Academic Editors: Alejandro Rescia and Carmelo Maria Musarella

Received: 6 May 2022
Accepted: 7 July 2022
Published: 11 July 2022

1. Introduction

Biodiversity is intertwined with sustainability providing many direct and indirect benefits to mankind. Its monetary value is estimated on four different levels: genes, species, ecosystems, and functions [1]. Despite its importance, the United Nations Organization mentions that one million species are threatened by extinction [2]. Extinction rates of species belonging in various taxa had already started rising exponentially due to human activities more than twenty-five years ago [3]. The loss of biodiversity due to human activities is profound despite conservation efforts, as these activities combined with the upcoming climate change will affect global species abundance distributions [4,5]. Many studies suggest that the loss of biodiversity will not affect specific ecosystem functions, but rather the collective interactions and the overall ecosystem function, in such ways that biodiversity loss can have a much bigger impact [6]. Furthermore, the loss of these functions would negatively affect the economy, as large amounts of money would be required for their restoration [7].

In view of the fact that sources for species conservation are limited, main efforts and resources should be primarily focused on biodiversity hot spots, areas around the world with a plethora of species [8]. Greece has been found to host one of the main plant biodiversity centers in Mediterranean basin [9], mainly due its diverse geomorphology, climate, and rock substrates. Additionally, it is geographically located between Italy, Turkey, and the Balkans, and thus, parts of the country belong to the plant migratory routes connecting Greece and Anatolia [10]. As a consequence, the country hosts a plethora of rare or endangered species, others being geographically isolated in the numerous Greek islands, and others consisting of high mountain endemic flora [10–14]. Improving knowledge regarding the taxonomy, distribution, and population trends of threatened species is crucial for their prioritization in taking protection measures, due to heavy anthropogenic impacts and habitat destruction observed over the last decades [15]. Especially for Greece, the floristic profile of many areas is still inadequate or inaccurate, and they lack a systematic plant inventory [11,16,17]. However, protection and conservation efforts should be focused on biodiversity hotspots, not only because of the species' abundance, but because endemic species are more vulnerable to anthropogenic and natural disturbances, and suffer from habitat loss [18,19]. More specifically, in Greek islands, important endemic and threatened species in need of protection have been found in high-altitude areas [12]. Except for the isolated places that are biodiversity hot spots, urban and peri-urban areas might host species with high conservation value, which might have not been taken into consideration during urban planning. There are few data regarding the conservation value of plant biodiversity in cities, while very few Mediterranean cities have an urban plant diversity inventory, and our knowledge is limited. Thus, it is important to study local biodiversity and the disturbances that threaten it [20,21].

As cities expand, the use of peri-urban land is also intensified. As a result, forests share their borders with other land uses such as agriculture, infrastructure, and human settlements. Therefore, in the city borders (city-forest ecotone), the forests have a greater chance of getting degraded in comparison to those that are surrounded by natural areas [22]. Studies show that species and their composition significantly vary between the forest edge and forest interior [23]. The intensification of human activities poses a threat to peri-urban forest biodiversity, especially in spots closer to cities with growing populations, as they get more disturbed [24]. Soil and climate conditions combined with natural and human disturbances form the biodiversity of an ecosystem [25]. However, when human disturbances get too intense, e.g., in the peri-urban forests, they can negatively affect biodiversity and increase the risk for biodiversity loss. Urban development and fragmentation are a common problem to both urban forests and biodiversity [26,27]. Fragmentation and related disturbances are shown to be more intense near trails, viewpoints and in small forest areas. The increase of visitors' number results in greater degradation and changes in vegetation [24]. Another major problem for the biodiversity loss of degraded peri-urban forests is the invasion of alien species. Many of them often escaped from the ornamental plants used in urban areas [28]. Alien species grow in disturbed soil like the one found by the roadsides, and from there they spread into the forests. There is a negative correlation between the distance from the roads and the presence of alien plants [24,29]. Fragmentation allows alien plants, such as *Ailanthus altissima* (Mill.) Swingle, to spread into inner parts of the forest and negatively impact the understory vegetation and species abundance [30]. Other threats to peri-urban forest biodiversity are littering, plant collections, and recreational activities [26,31].

A good deal of studies around the world focus on the protection and conservation of plant species and biodiversity by investigating the changes in the ecosystems, as well as the way these changes affect species status. This effort is supported by the studies related to the protection and conservation of genetic diversity, which is the key for adaptation to environmental changes, and secures the species survival. Genetic diversity is threatened when an ecosystem is subjected multiple times to enduring forms of human disturbance [18,32–34]. The effects of disturbances on ecosystems can be estimated by measuring quantitative ecological parameters indicating the biodiversity status of an ecosystem, such as species richness, number of alien or ruderal species, etc. These parameters also provide answers regarding the relations of forest functions and biodiversity [35]. Disturbances have different effects on ecosystems; thus, the evaluation criteria and methods may differ in each case or be broad enough to apply to all [36]. In any case, it is necessary to obtain more research data, especially on Greek biodiversity [20,21,37], where even though the country is a biodiversity hot spot, there is still a great lack of important knowledge on species distribution and population data [13,38,39]. Records of species abundance is also crucial to avoid their overexploitation for human needs [40]. In Greece, there have been many cases where native or rare plants were threatened due to excessive collection and use from locals or human activities, such as livestock grazing [41,42].

The aim of the study was to explore the plant species' diversity and conservation value of the peri-urban forests of Thessaloniki, northern Greece, as well as the disturbances that may affect ecosystems floristic and conservation status. The hypothesis was that the ecosystems closer to city, being more influenced by human, would present lower biodiversity indices and conservation value as a result of human impacts. A variety of floristic indices were calculated based on field data collection, in order to evaluate the ecological parameters connected to biodiversity. To obtain a more solid understanding of present and future problems due to human activities, we observed and compared human disturbances presented in every ecosystem type. Specifically, the detailed aims of the study were: (a) to determine the plant species richness and floristic composition within different ecosystem types prevailing in the two peri-urban areas; (b) to record the number of plant species, ground cover (%), and biodiversity index in each layer (tree, shrub, and grass layer) in each ecosystem type; (c) to explore any floristic similarities among the different forest ecosystems; (d) to explore any differences in native, non-native, adventitious (alien), and ruderal species between the studied ecosystems; (e) to record the type of anthropogenic and natural disturbances; and finally, (f) to evaluate conservation values C of plant species in each forest ecosystem type [20,43–45].

2. Materials and Methods

2.1. Study Area

The study was carried out in two peri-urban forests of Thessaloniki, northern Greece, Seich Sou forest, and forest in Mountain Hortiatis (Figure 1). The first is located just close to the city of Thessaloniki, laying between 40°35′ N to 40°40′ N and 22°55′ E to 23°05′ E. The total area of the forest is 3,025.25 ha, and it is a result of plantations during the 1920s [46,47]. The vegetation of the area belongs to the order of *Quercetalia pubescentis*, more specifically to the alliance of *Ostryo-Carpinion*, and the association of *Coccifero-Carpinetum*. It hosts 277 plant species with *Pinus brutia* Ten being the main tree species [47,48]. It has a typical Mediterranean climate with cold winters, 416 mm annual precipitation, mean temperature 15.8 °C and a dry period lasting from May until the middle of September [48]. The average altitude is approximately 302 m. The soils are mostly brown forest with frequent absence of A and B horizons in the south aspects. In the north, there are mostly metasedimentary rocks, and in the south, there are sedimentary and metamorphic rocks [47].

Mountain Hortiatis is located approximately 30 km far from the city of Thessaloniki, in Central Macedonia, northern Greece, between 40°37′ N to 40°35′ N and 23°06′ E to 23°08′ E and has a total forest area of 1350 ha [49,50]. The altitude varies a lot, from 590 to 1300 m [49]. There are three vegetation zones, *Ostryo-Carpinion orientalis* (shrubs with *Quercus coccifera*) *Quercion confertae* (oak and chestnut forests), *Fagion moesiacae* (beech forests) belonging in the order *Querco-Fagetea* [51]. In the southern part of the mountain exist plantations of *Pinus nigra* [50]. Annual precipitation is 449 mm with a mean temperature of 15.6 °C. The dry season lasts 1–1.5 months, with August being the driest month [47,51]. Soil is medium to highly eroded, with medium depth and fertility [47,50]. The bedrocks vary, including sandstone, schist, phyllite, limestone, gneiss, and a mixture of limestone, igneous, and hyperbasic rocks. Many important plant species have been very recently recorded in the area, including rare or threatened species [51], e.g., a first occurrence of the species *Colchicum soboliferum* (C.A.Mey.) Stef., native to Greece, and the species *Colchicum* *tulakii* Th. Giannakis & al., which should be protected since their appearance in the area is geographically isolated [52,53].

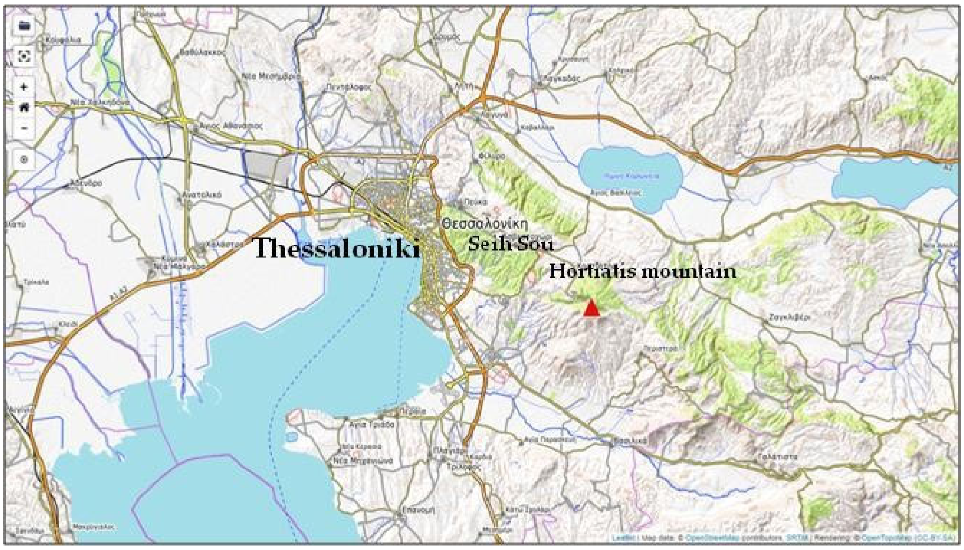

Figure 1. Map showing the study area.

2.2. Sampling and Floristic Data Analysis

In total 26 plots were sampled, within six forest ecosystem types of different size as follows (Table 1, Figure 2): Maqui vegetation (5 plots of 100 m^2), *Pinus brutia* forests (5 plots of 200 m^2) in Seich Sou peri-urban forest; *Pinus nigra* J.F. Arnold (5 plots of 200 m^2), *Fagus sylvatica* L. (5 plots of 300 m^2), *Quercus frainetto* Ten. And *Castanea sativa* L. (3 plots of 300 m^2) in forests of Mountain Hortiatis. The visits in the study areas were undertaken throughout the whole year to gather observations and supplementary materials (photographs, notes, samples from plant material, discussions with visitors), while the plant sampling was conducted during 2/4/2021 to 22/5/2021. The plots were chosen in areas approximately 30 m from the road in places that were accessible by visitors. In each plot, we also recorded the environmental variables such as elevation and exposure, and we measured the tree height. Finally, from all our visits in the study area, we made a record of observed disturbances to obtain a more solid understanding of the problems in every ecosystem and the human pressures. Apart from the general data for each plot described in Table 1, we also recorded all plant species that appeared in the ground, shrub, and tree layer, and their abundance according to Domin scale, taking values in a scale of 1–10 [54]. We collected specimens that were identified on spot with the help of a preexisting plant record enriched with personal photographs and notes [51] or given codes to some in order to be later identified in the laboratory. Over 95% of species identified to species level, except for a few species that identified at family level (e.g., for specimens without fruit or flower), or genus. A complementary plant sampling was carried out the following year (2022) in late spring in order to identify all the recorded plants at species level. To assess the floristic quality and biodiversity status we used the Shannon index, as well as and Sørensen indices (Cs) to estimate alpha (α) and beta (β) diversity [37]. We also compared the plant families found in each ecosystem, as well as the presence of non-native, alien, and ruderal species, based on the insights given in the literature [55,56]. For every identified plant species, we determined a conservation value C, based on literature data, Greek, and international databases (e.g., Vascular Plants Checklist of Greece, and Global Biodiversity Information Facility (GBIF)), and three experts judgment, and then we calculated a mean of C values for every ecosystem [43–45]. Analytically, all the recorded plant species were characterized as follows [43]:

- *0: Non native species, the species is obligate to ruderal areas (e.g., Solanum eleagnifolium* Cav.*)*
- *1–3: Native taxa that found in a wide variety of plant communities and very tolerant of disturbance, and found in disturbed sites (e.g., Chrysopogon gryllus* (L.) Trin., *Osyris alba* L.*).*
- *4–6: Native taxa that typically associated with a specific plant community, but tolerate moderate disturbance (e.g., Teucrium polium* L., *Thymus vulgaris* L.*).*
- *7–8: Native taxa that is typical of well-established communities, which have sustained only minor disturbances. These plants have a fidelity to native lands of high quality (e.g., Silene italica* (L.) Pers., *Sanicula europaea* L.*).*
- *9–10: Native taxa with high degrees of fidelity to a narrow range of synecological parameters and restricted to narrow ecological conditions, with low tolerance of disturbance, rater 95% confident these plants were growing in an undisturbed or native land of high quality (e.g., Athyrium filix femina* (L.) Roth, *Saxifraga bulbifera* L.*).*

Table 1. Plot samples description. Values of tree height are means and standard error of mean.

Plot N.	Ecosystem	Aspect	Average Tree Height (m)	Tree Layer	Shrub Layer	Ground Layer	Altitude (m)
				Cover (%)			
1	*P. brutia*	NW	8 (0.76)	46	13	30	222
2	*Maqui*	E	7 (1.08)	4	12	40	287
3	*Maqui*	SW	1.2 (0.47)	0	40	40	319
4	*P. brutia*	W	9 (0.82)	85	2	15	302
5	*P. brutia*	S	10 (0.83)	90	35	15	325
6	*Maqui*	S	3.5 (0.64)	7	20	65	362
7	*P. brutia*	S	11 (0.91)	70	10	25	268
8	*P. brutia*	W	13.5 (1.06)	70	5	20	288
9	*Maqui*	SW	6 (1.04)	4	60	50	266
10	*Maqui*	S	2 (0.32)	0	40	70	269
11	*P. nigra*	N	10 (0.44)	35	55	20	1007
12	*P. nigra*	N	9 (0.48)	55	60	30	1024
13	*P. nigra*	W	20 (1.25)	65	20	25	844
14	*P. nigra*	W	20 (1.08)	50	30	10	872
15	*P. nigra*	W	21 (1.16)	25	60	80	926
16	*F. sylvatica*	E	22 (1.22)	95	10	15	1022
17	*Q. frainetto*	NE	20 (1.48)	45	5	90	955
18	*Q. frainetto*	S	19 (1.40)	85	5	50	1004
19	*F. sylvatica*	N	20 (1.26)	95	15	50	997
20	*F. sylvatica*	NE	18 (1.08)	85	10	50	1014
21	*Q. frainetto*	E	18 (1.41)	90	5	35	1000
22	*C. sativa*	N	23 (1.19)	80	5	30	1003
23	*F. sylvatica*	N	23 (1.10)	95	10	5	984
24	*F. sylvatica*	N	22 (1.28)	85	10	10	994
25	*C. sativa*	N	13 (0.65)	90	5	40	917
26	*C. sativa*	N	11.5 (0.52)	100	15	35	863

Finally, for the estimation of the characteristics of the soils in each ecosystem type, a soil sample from the surface layer (0–20 cm) was taken from each plot (center point) and was transported to the laboratory for physical and chemical analysis. Laboratory analysis included organic matter content, pH determination, total nitrogen, and mechanical analysis (particle size distribution). Soil depth was measured in the field.

2.3. Statistical Data Analysis

Statistical analysis of the collected data was performed with the SPSS® software v. 23.0 (SPSS Inc., Chicago, IL, USA). One-way ANOVA was used to test significant differences between the Shannon biodiversity index determined for each ecosystem type, and per layer, as well to C conservation values derived from the recorded plant species in each ecosystem. LSD and Waller-Duncan tests were conducted to compare the computed mean values. All statistical analyses were conducted using the critical significance level $\alpha = 0.05$.

Figure 2. The studied forest ecosystems, in the peri-urban area of Thessaloniki, northern Greece.

3. Results

3.1. Ecological Characteristics of the Studied Forest Ecosystems

The two forest ecosystems of Seih Sou (*Pinus brutia* forest and Maqui vegetation) are distributed in the lower altitude (Table 1), in the more degraded areas, adjacent to the city of Thessaloniki. They were mainly found in southern and west-southern slopes. On the contrary, all the forest ecosystems of Hortiatis are distributed in higher altitudes and in generally northern slopes. Two of the studied ecosystems, those of pines, originated from plantings, while the rest four, all broadleaves, are of natural origin. However, one of them (Maqui ecosystem) is distributed in the lower altitude, in degraded areas because of the long history of human presence [50]. All the forest ecosystems in Hortiatis mountain present a dominant tree story, excelling the 20 m in height, while the two types of ecosystems in Seih Sou present either a scattered tree layer of low height (average 6–8 m) in Maqui ecosystem, or a continuous tree layer of low height (average 10–12 m).

According to the analysis of the soil samples taken, the soil characteristics in the studied forest ecosystems show great differences in terms of physical and chemical properties, especially between the Seih Sou forests and forest ecosystems of mountain Hortiatis

(Table 2). The particularly shallow depth of soil observed in the first case (soil depth less than 30 cm) greatly differs from the soil depth in the Hortiatis forest ecosystems, (soil depth over 50 cm in all types of forest ecosystems), except for the case of *Pinus nigra* forest which was found to be established (by plantings) in shallow soils with an average soil depth of 34.8 cm. Soils are neutral in the case of Seih Sou forests and slightly acid in the forest ecosystems of Hortiatis mountain. Their concentrations of organic matter and nitrogen in the surface layer (0–20 cm) was moderate in the first case (average values ca 3.0–3.5%, and ca 0.20%, respectively), with an increase trend in the second case, up to 5.8% and 0.34%, respectively; the higher values being observed in *Castanea sativa* forest.

Table 2. Soil characteristics in the studied forest ecosystems.

Ecosystem Type/Soil Characteristics	*Pinus brutia* Forest	Maqui Ecosystem	*Pinus nigra* Forest	*Fagus sylvatica*	*Quercus frainetto*	*Castanea sativa*
Soil depth (cm)	29.5	18.9	34.8	63.2	50.1	58.4
Organic matter (%)	3.4	3.1	4.0	5.5	4.5	5.8
pH	7.2	7.2	6.9	6.7	6.6	6.7
Nitrogen (%)	0.21	0.18	0.23	0.31	0.25	0.34
Soil texture	SL *	SL	SL	SL	SL	SL

* SL = Sandy loam.

3.2. Species Richness and Floristic Composition of the Studied Peri-Urban Ecosystems

3.2.1. Species Richness

The total number of plant species recorded in each ecosystem type and the number of species and ground cover (%) observed in each layer (tree, shrub, and grass layer) are presented in Table 3, while the full list of plant species recorded in all sapling plots is presented in the Supplementary Table S1. Fewer species were recorded in the Seich Sou ecosystems of *Pinus brutia* and maqui vegetation (54 species per ecosystem) compared to the ecosystems of Hortiatis. Among the prevailed ecosystems of Mount Hortiatis, the lowest plant species richness was found in *Fagus sylvatica* ecosystem (55 plant species), followed, in ascending order, those of *Pinus nigra* (70 species), *Castanea sativa* (73 species), while *Quercus frainetto* forest was the most species-rich forest (83 plant species). The degree of tree canopy cover and the resulting light availability in the understory varied, allowing species with different light requirements to thrive. Regarding canopy cover of the tree layer, *F. sylvatica* ecosystem had the highest cover (91%). Thus, there were some beech stands where species presence in the ground layer was zero due to the very high (dense) cover of the tree layer. The lowest cover in the tree layer was found in Maqui vegetation (5.0%), as trees only occurred randomly and had poor growth and low height. In the shrub layer, the highest cover was found in *P. nigra* forest, due to the abundance of shrubs belonging mainly to the *Rubus* and *Rosa* genus, and some to *Juniperus*. The lowest cover in the shrub layer was found in *Q. frainetto*, with a small presence of plants like young *Ilex aquifolium* L. and species from the *Rubus* and *Rosa* genus. In the grass layer, the highest cover was in *Q. frainetto*, with an abundance of small flowering plants, and the least cover in *P. brutia* forests, as the pine needles were inhibiting the recruitment of herbaceous species, and thus, the species recorded were mainly those growing in the small stand openings.

3.2.2. Number of Plant Species Families per Ecosystem Type

Table 4 presents all the plant families of the recorded species in each forest ecosystem type. *Castanea sativa* forest was found to be the ecosystem which comprising the most plant families (30 families). *Quercus frainetto* comprising 29 families, Maqui vegetation, and *Pinus nigra* comprising both 28 families, *Fagus sylvatica* forests 24 families, while the least number of families was found in *Pinus brutia* forests (22 families). Some families are known to contain a lot of ruderal species. In the ecosystems of Seich Sou, the dominant plant family is *Asteraceae*, while in the ecosystems of Hortiatis the dominant family is *Roseaceae*. These two families are also widely present in all ecosystems. The second most present family is the family of *Poaceae*, while the families of *Fabaceae* and *Lamiaceae* are also common in all ecosystems.

Table 3. Plant species richness and cover of each layer (%) for the six studied ecosystems.

Ecosystem Type	*Pinus brutia*	*Maqui*	*Pinus nigra*	*Fagus sylvatica*	*Quercus frainetto*	*Castanea sativa*
Total plant richness	54	54	70	55	83	73
Tree layer						
Number of species per plot	1	0.6	1.4	1.8	1.33	2.67
Cover (%)	72.2	5.0	46.0	91.0	73.33	90.0
Shrub layer						
Number of species per plot	2.8	3.6	4.2	1.6	2.0	2.67
Cover (%)	13.0	34.4	45.0	11.0	5.0	8.33
Ground layer						
Number of species per plot	16.2	17.8	21.6	17.4	45.0	39.33
Cover (%)	21.0	53.0	33.0	26.0	58.33	35.0

Table 4. Distribution of plant families in the six studied forest ecosystems.

Plant Family	*Pinus brutia*	*Maqui*	*Pinus nigra*	*Quercus frainetto*	*Fagus sylvatica*	*Castanea sativa*
	Number of Plant Species					
Alliaceae	0	1	0	1	1	1
Amaranthaceae	0	1	0	0	0	0
Anacardiaceae	2	1	0	0	0	0
Apiaceae	0	0	0	1	0	3
Aquifoliaceae	0	0	0	0	1	1
Aristolochiaceae	0	0	0	1	0	0
Asparagaceae	2	3	3	2	1	2
Aspleniaceae	0	0	1	4	0	1
Asteraceae	8	9	6	5	3	7
Betulaceae	0	0	1	0	0	2
Boraginaceae	3	1	0	1	1	1
Brassicaceae	0	3	1	2	2	2
Campanulaceae	0	0	1	0	0	2
Caprifoliaceae	1	0	1	1	0	0
Caryophyllaceae	0	2	2	4	2	2
Cistaceae	2	2	1	0	0	0
Crassulaceae	0	2	1	0	0	0
Cupressaceae	1	1	1	1	1	1
Dennstaedtiaceae	0	0	0	0	1	1
Dispacaceae	0	0	0	1	0	0
Ephedraceae	0	1	0	0	0	0
Ericaceae	0	0	1	0	0	0
Euphorbiaceae	1	1	0	0	0	0
Fabaceae	2	4	3	4	2	5
Fagaceae	2	1	6	3	3	3
Gentianaceae	0	1	0	0	0	0
Geraniaceae	2	1	0	0	0	0
Hypericaceae	0	1	1	2	1	1
Juncaceae	0	0	3	1	2	1
Lamiaceae	7	4	6	5	2	3
Liliaceae	0	0	0	0	1	1
Morinaceae	0	1	0	0	0	0
Oleaceae	2	1	1	1	0	0
Orchidaceae	0	0	1	3	4	3

Table 4. *Cont.*

Plant Family	*Pinus brutia*	*Maqui*	*Pinus nigra*	*Quercus frainetto*	*Fagus sylvatica*	*Castanea sativa*
	Number of Plant Species					
Pinaceae	1	1	2	0	0	0
Plantaginaceae	1	0	2	1	2	2
Poaceae	6	7	5	6	5	4
Polygonaceae	0	0	1	1	1	1
Polypodiaceae	0	0	0	1	0	1
Primulaceae	0	0	1	3	3	2
Pteridaceae	0	1	0	0	0	0
Ranunculaceae	1	1	1	7	1	5
Resedaceae	0	1	0	0	0	0
Rhamnaceae	1	0	0	0	0	0
Rosaceae	3	1	10	9	11	11
Rubiaceae	1	0	1	2	1	1
Santalaceae	1	1	0	0	0	0
Saxifragaceae	0	0	1	0	0	1
Scrophulariaceae	1	2	0	2	0	1
Ulmaceae	0	0	0	1	1	0
Violaceae	1	0	2	3	1	1

3.2.3. Plant Biodiversity Index for the Studied Ecosystems

In Table 5, the mean of the Shannon biodiversity index for each forest ecosystem, per layer and totally, is shown. In the tree layer, the Shannon biodiversity index was greatly varied; the significantly highest biodiversity was recorded in the *Castanea sativa* forests, due to the presence of scattered individuals of other tree species, such as *Quercus* sp., *Corylus avellana* L., *Carpinus betulus* L., and *Fagus sylvatica*. On the other hand, a zero value in the Shannon biodiversity index in the tree layer was found in *Pinus brutia* forest (as tree layer is consisted of only one tree species) and Maqui vegetation (as tree layer was absent). In the shrub layer, the higher Shannon index (1.08) was recorded in the Maqui ecosystem, dominated by the species *Quercus coccifera* L., *Juniperus communis* L., *Asparagus acutifolius* L., *Cistus criticus* L., and in the *Pinus nigra* forest, with dominant shrub species *Rubus* sp. and *Rosa* sp. On the contrary, the fewest species were found in the *Fagus sylvatica* forests, with the shrub layer consisting mostly of young individuals of beech without the presence of any other plant species. In the grass layer, the higher biodiversity index was recorded in the *Quercus frainetto* and *C. sativa* forests. Furthermore, in *C. sativa* forests, there were observed many plant species not found in any other forest ecosystems of Hortiatis, such as the species *Polygonatum odoratum* (Mill.) Druce. In the more remote plots, regardless the type of ecosystem, there were found a lot of orchid species. The lowest number of species were recorded in *P. brutia* forest, as the species needles usually prevent other species from establishing themselves.

Table 5. Means of Shannon biodiversity index for each ecosystem type. Means in the same column followed by different letters indicate significant differences between them.

Ecosystem	Tree Layer	Shrub Layer	Grass Layer	Totally
Pinus brutia	0.00d	1.0026a	2.6031c	2.5748c
Maqui	0.00d	1.0837a	2.6865c	2.8004bc
Pinus nigra	0.3195b	1.0618a	3.1802b	2.9552b
Quercus frainetto	0.1625c	0.8958a	3.6791a	3.6276a
Castanea sativa	0.5468a	0.9981a	3.5987a	3.4825a
Fagus sylvatica	0.3074b	0.6590b	2.6110c	2.4742c

3.3. Patterns of Floristic Similarity and Beta Diversity between the Studied Forest Ecosystems

The rate of species loss and gain between the studied forest ecosystems (β diversity), calculated with the Sørensen index, is shown in Table 6. There was a broad range of β diversity, ranging from the extremely low value of 0.0315 Cs observed between *Castanea sativa* forest and *Pinus brutia* forest, as well as between *C. sativa* forest and Maqui vegetation, to the relatively high value of 0.531 Cs between *C. sativa* and *Fagus sylvatica* ecosystems, indicating the high floristic similarity between *C. sativa* and *F. sylvatica* ecosystems, and the weak similarity between *C. sativa* and *P. brutia* and Maqui vegetation. Analytically, *P. brutia* floristic pattern matched the most with Maqui vegetation with 0.398 Cs. *P. nigra* matched the most with *Quercus frainetto* (0.3529 Cs), and it also showed approximately 30% similarity with *F. sylvatica* and *C. sativa* forests. *Quercus frainetto* forests showed the highest similarity with *C. sativa* with 0.4348 Cs, and *F. sylvatica* with 0.4347 Cs. *Fagus sylvatica* matched the most with *Q. frainetto* with 0.4347, while the least with *P. brutia* with 0.055 Cs. Finally, *C. sativa* matched the most with *Q. frainetto* with 0.4358 Cs and almost did not match at all with *P. brutia* and Maqui vegetation with 0.03149 Cs.

Table 6. Floristic similarities (Sørensen Cs index) between the different ecosystems.

Sørensen Index	***Pinus brutia***	***Maqui***	***Pinus nigra***	***Quercus frainetto***	***Fagus sylvatica***	***Castanea sativa***
P. brutia	-	0.3889	0.1129	0.0730	0.0550	0.0315
Maqui	0.3889	-	0.1129	0.0876	0.0734	0.0315
P. nigra	0.1129	0.1129	-	0.3529	0.336	0.3077
Q. frainetto	0.0730	0.0876	0.3529	-	0.4348	0.4359
F. sylvatica	0.0550	0.0734	0.336	0.4348	-	0.5312
C. sativa	0.0315	0.0315	0.3077	0.4359	0.5312	-

3.4. Disturbances, Alien and Ruderal Species

3.4.1. Recorded Disturbances

All the observed anthropogenic and natural disturbances in the studied ecosystems are summarized in Table 7. Some of these are direct, such as littering, while others are a result of human neglect, lack of management, or lack of environmental education in citizens. The most disturbances were recorded in the *Pinus brutia* forests, and the least in the *Castanea sativa* forests. The observed disturbances fall into four big categories: (1) presence of littering or garbage; (2) disturbances from animals, such as grazing and diseases from insects; (3) disturbances linked to the number of visitors and their activities such as trails, recreational spots, and foraging; and (4) disturbances linked to ecological degradation caused by humans such as forest fires, alien species, and lack of management. Undoubtedly, the most disturbances were recorded in areas close to viewpoints, recreational spots, spots near facilities, and open stands with high accessibility. Stands with high inclination or far from trails were much cleaner, with low presence of disturbances. What is important to note is that there was a lot of intentional littering, especially in Seich Sou ecosystems. Alien plant species were also recorded in abundance, especially in the sides of big roads or open places. More specifically, the invasive *Solanum eleagnifolium* was recorded in high numbers in Seich Sou forest. Visitors were also disturbing the environment by collecting plants in large numbers, using heavy vehicles, brought pets into the forest, and did not respect the rules of forest protection.

Table 7. Observed disturbances in the studied peri-urban ecosystems.

Observed Disturbances and Problems	*P. brutia*	*Maqui*	*P. nigra*	*F. sylvatica*	*Q. frainetto*	*C. sativa*
Presence of litter and detritus	X	X	X	X	X	X
Erosion or soil disturbances	X	X	X	X	X	X
Presence of trails	X	X	X	X	X	X
Motorcycles traffic	X		X	X		X
Plant diseases and harmful insects	X		X			
Presence of burned trunks	X	X				
Presence of grazing of wild animals	X	X	X			
Presence of pets	X	X	X	X	X	
Parking or passing of cars	X		X	X	X	
Presence of alien species	X	X				
Plant foraging from visitors	X	X				X
Recreation structures	X	X		X	X	

3.4.2. Presence of Adventitious, Invasive (Alien) and Ruderal Species in Each Ecosystem Type

Any adventitious species were not found within any sampling plot, except for some *Cupressus arizonica* Greene individuals that were recorded in *Pinus brutia* forest due to reforestation efforts after the wildfire of 1997. Moreover, some alien plant species such as *Ailanthus altissima*, *Solanum eleagnifolium*, *Phytolacca americana* L., *Robinia pseudoacacia* L., and *Oenothera* sp. were found near the side of the road, or very close to the studied plots in the peri-urban forest of Seich Sou, in the ecosystems of *P. brutia* and Maqui vegetation, as a result of human presence.

Regarding the presence of ruderal species, in both Seich Sou ecosystems, we recorded higher number of ruderal species than in Hortiatis ecosystems being 24.07% of the whole species recorded (Table 8). The ruderal species in Seih Sou ecosystems belong mainly to the families *Asteraceae*, *Poaceae*, *Alliaceae*, and *Scrophulariaceae*, while, in Hortiatis ecosystems, the ruderal species were scattered in different plant families. In *Castanea sativa* ecosystems, we recorded the least ruderal species (6.8%). *Pinus nigra* forest had also relatively few ruderal species (8.57), as both *C. sativa* and *P. nigra* forests had dense canopies which did notfavor plant growth in the understory. For the same reason, the ruderals accounted for 9% of the total plant species in *Fagus sylvatica* ecosystems, while in *Quercus frainetto* we found the highest percentage of ruderals for Hortiatis ecosystems, that being 13.2%.

Table 8. Presence of native, adventitious, invaders and ruderal species in each ecosystem type.

Presence of Native, Ivasive and Ruderal Species	*Pinus brutia*	*Maqui*	*Pinus nigra*	*Fagus sylvatica*	*Quercus frainetto*	*Castanea sativa*
Number of native species	53	54	70	55	83	73
Number of non-native species	1	0	0	0	0	0
Number of invasive species	0	0	0	0	0	0
Percentage (%) of ruderal species	24.07	24.07	8.57	9.09	13.25	6.85

3.4.3. Conservatism Values C of Plant Species Recorded in Each Ecosystem Type

The average of plant species C conservation values in each ecosystem type are shown in Table 9, for a = 0.05. These values were computed based on the defined conservation values C for all plant species recorded in each ecosystem type. The *Castanea sativa* and *Fagus sylvatica* forests present significantly highest means with C, (6.5 and 6.4 respectively), followed by the *Quercus frainetto* ecosystems with a mean C value of 6.0, and then *Pinus nigra* forest with a mean C value of 5.6. This indicates that all these ecosystems host important plant species, with some of them presenting high C values. On the contrary, in Seich Sou ecosystems, most recorded species have a low C value, and few species have moderate or high C values. Maqui vegetation has a mean of C values equal to 4.31, and *Pinus brutia* is the ecosystem with the least important species for conservation with a mean C 4.24. It is worth mentioning that the standard error observed between the plots was low in all ecosystem types, ranging between 0.18 to 0.28. Similarly low was the differences between upper and lower limits of the observed values in the different plots of each ecosystem type (Table 7).

Table 9. Statistics of C conservation values derived from the recorded plant species in each ecosystem type. Means followed by different letters indicate significant differences between them, a = 0.05.

For a = 0.05	*Pinus brutia*	*Maqui*	*Pinus nigra*	*Fagus sylvatica*	*Quercus frainetto*	*Castanea sativa*
Mean of C values	4.24 c	4.31 c	5.60 b	6.40 a	6.00 ab	6.51 a
Standard deviation	1.34	1.58	1.92	2.05	1.94	2.02
Standard error	0.18	0.21	0.23	0.28	0.21	0.24
Upper limit of CI	3.88	3.89	5.15	5.86	5.58	6.04
Lower limit of CI	4.60	4.74	6.05	6.94	6.42	6.97

4. Discussion

According to the results obtained by field data, it is indicating that the forest ecosystems of the suburban area of Thessaloniki, northern Greece, those appearing in the peri-urban forest of Seich Sou, and those of the mountain Hortiatis, present important floristic differences and are subjected to a different scale and type of disturbances. Previous studies report that the abundance of plant species in a forest ecosystem is affected by the dominant tree species, the density and composition of the overstory, the environmental factors, and the silvicultural treatments [37,57]. Additionally, biodiversity in the understory is affected by the main tree species in the overstory [58]. Other studies mention that the biodiversity of the forest layers below the understory are more depended on the disturbances and forest type [52].

In the present study, the ecosystems of the Hortiatis mountain present higher species richness and α diversity than the Seih Sou ecosystems. Especially the oak and chestnut stands, with a loose canopy, which allows the light to reach in the understory exhibited the highest values of biodiversity indices. The richest tree overstory was observed in the chestnut forest, while in the shrub layer, Maqui vegetation hosts the most species. Other studies in Greece suggest that the greatest α biodiversity exists in the black pine ecosystems, then in those of oak and finally beech [37]. Moreover, it is reported that coniferous forests of low altitude that recently burned, host high biodiversity in the understory as the plant biomass burned in the overstory, such as pine needles, has a positive effect in the biodiversity of stands, which are burned frequently and maintain an open canopy [59]. However, in the present study, most species were recorded in the broadleaf ecosystems in the Mountain Hortiatis instead of *Pinus brutia* in Seich Sou which had a recent history of forest fires. Although, Seich Sou and Hortiatis forest ecosystems don't belong to areas with high biodiversity compared to the country status [60,61], however, they still present relatively high biodiversity, presenting high Shannon index values (2.47 to 3.63), taking into account that in forest ecosystems the Shannon index ranges from 1.5 to 3.5 [62]. With regard to floristic similarities, like findings of other similar studies (37), oak ecosystems have more floristic similarities with beech ecosystems than with forests of black pine.

Despite the rich biodiversity, only the chestnut and beech ecosystems present a mean of conservation values, which implies that they host important species (species with high conservatism values C, 7–9). Ecosystems of Hortiatis have a conservation value ranging from 5.6 (*Pinus nigra* forest) to 6.5 (*Castanea sativa* forest). On the other hand, Seich Sou ecosystems present relatively low conservation values ranging from 4.24–4.31, and therefore they have few species worthy of conservation. According to the literature, conservation values between 4–6 imply plants that are typical and autochthonous in a specific area that can withstand moderate disturbances [43,44,63]. Based on our results, Seich Sou forest presents a lot more disturbances than Hortiatis and welcomed more visitors due to the immediate proximity to the Thessaloniki city. Moreover, disturbances are more intense in low altitudes near populated areas or in easily accessible areas [52,64]. Studies thus far show contradictory visitors' preferences; they prefer mixed quiet forests that maintain a natural look, but they also want convenience and amenities such as paths and parking spots. At the same time, they state that the presence of water elements and the abundance of plant species positively affect the attractiveness of a forest [65,66]. However, the least disturbances were recorded in the chestnut forest, which appears in areas of high slope inclination, isolated, and far from trails or major roads.

In all ecosystems, the main disturbance due to visitors' activities was littering, mostly packaging from food and drinks. The majority of the disturbances was found close to roads, facilities, or places of a certain interest such as viewpoints. Finally, grazing appears to be a threat to all ecosystem types, and it was also present in Seich Sou ecosystems and in *Pinus nigra* forest as well [61]. Although it is mentioned that grazing might positively affect the biodiversity in *Pinus brutia* forests [67], this does not seem to be the case in the present study. Based on our data, disturbed ecosystems which are largely affected by human activities, usually present many ruderal species. Thus, the ecosystems of Seich Sou are dominated by plant families that host a lot of ruderal species. On the contrary, the ecosystems of Hortiatis mountain have a low presence of ruderal species (Table 6). Some alien plant species were also found, especially in the *P. brutia* forests, where the most ruderal species were recorded similarly to the Maqui ecosystem [56]. It is also important to note that alien species were only recorded outside the sampling plots, in open forest stands or close to the roads of the *P. brutia* forest and Maqui ecosystem, indicating that many of them cannot survive inside a dense forest. In the case of *Solanum eleagnifolium*, studies showed that the substances of the leaves from species such as *P. brutia*, *Quercus coccifera*, *Quercus pubescens* Willd. and *Cupressus sempervirens* L. inhibit the growth of its seeds [68].

There are many disturbances that can only be dealt with by implementing policy measures such as regulating grazing, but there are many disturbances that can only be dealt with by altering the behavior and attitude of people. It is important to educate people about the damage humans can cause in biodiversity and forests such as the unmindful collecting of plants, the use of heavy vehicles in forested areas, and the unnecessary damage to plants wrought by mechanical devices. Management of forests must be carried out along with appropriate silvicultural treatments in order to improve the stand structure of the forests and protect them from forest fires [69]. Even though forest regeneration of Seich Sou was successful after the 1997 forest fire, it is necessary to implement silviculture measures such as thinning and pruning to maintain the stand structure and protect them from future fires [70]. Thinning in the *P. brutia* forests of Seich Sou had positive impact in the structure of stands by promoting the growth of trees, helping the differentiation of young stands and accelerated fruition [71], and increases the horizontal growth of trees [72]. Thinning in the tree layer in plantations with coniferous species exhibited a positive effect on the diversity of the understory and the abundance of species, creating multiple groups of plants with different growth stages and thereby enhancing the benefits of biodiversity [73]. Similarly, research about man made *P. nigra* forests in Greece showed that thinning with positive selection can improve the productivity of forests and enhance their ecosystem functions [74]. For beech and chestnut ecosystems, it would be beneficial to plan special studies for their sustainability, as they are of small size, have high floristic diversity, and are biogeographically isolated. More specifically, Hortiatis beech forests belong in a separate ecological and biogeographical group than all other beech forests in Greece [75]. The kind and intensity of silvicultural treatments are the most important factors which define the floristic composition of chestnut forests and their sustainability [76]. At the same time their mortality is increased when they are growing in dry conditions and under the pressure of goat grazing, such as it is happening at the chestnut forest of Hortiatis. Therefore, it is crucial to give special attention while planning and implementing targeted silvicultural measures [77].

Finally, during the collection of the data, the city of Thessaloniki was in a total lockdown due to COVID-19 restrictions. The number of visitors vary depending on the season, day, hour, and weather conditions [78]. Many research studies have shown that forest visitors are increased during lockdowns, which was also the case in Thessaloniki [79–81]. Therefore, the presence of disturbances, especially trash and litter, might differ significantly from other years.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14148497/s1, Table S1: Alphabetical list of the plant species recorded in the studied ecosystems.

Author Contributions: Conceptualization, P.G. and L.-M.P.; methodology, P.G. and L.-M.P.; software, L.-M.P. and M.T.; validation, P.G. and M.T.; formal analysis, L.-M.P.; investigation, L.-M.P.; resources, P.G.; data curation, L.-M.P. and M.T.; writing—original draft preparation, L.-M.P.; writing—review and editing, P.G. and M.T.; supervision, P.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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