Article

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Plant diversity of olive groves under different management practices: a case study on Lesbos Island (East Aegean area, Greece)

Abstract

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The Mediterranean Basin is evolving due to human - nature interactions. The management of agroecosystems strongly affects plant diversity. Olive groves cover 19% of the cultivated area in Greece of which 8% is organic, cultivated using environment-friendly farming practices, while the rest includes conventional (intensive) or abandoned olive groves. Lesbos, the third-largest island of Greece, is characterized by high plant diversity. The current study aims to investigate plant species diversity of olive groves under different management practices. Sampling activities have been carried out in 65 plots. Field surveys to sample the vascular flora and vegetation were performed between April and May of 2020 and 2021. More than 210 plant taxa have been recorded in the studied olive groves. The results showed that organic olive groves are characterized by a rich and diverse flora, mainly dominated by therophytes and especially of annual leguminous species indicating moderate long-term human interference. Intensive olive groves have a poor and rather common vascular flora also dominated by therophytes. Abandoned olive groves present a rather poor but diverse flora, mainly dominated by chamaephytes, hemicryptophytes and phanerophytes and by a lower proportion by annual plants, depending also on the time lapse after abandonment.

Key words: Mediterranean ecosystems, biodiversity, intensive olive cultivation, α-diversity, β-diversity.

Introduction

The occurrence of olive trees is a reliable index of Mediterranean-type ecosystems (Blondel & al. 2010) and *Olea europaea* L. is possibly the most emblematic of all Mediterranean plants (Thompson 2020) since ancient times; that is why, according to the Greek Mythology, ancient gods such as Zeus and Athena were protectors of the olive tree and its cultivation (Loumou & Giourga 2003).

The cultivation of olive groves in the Mediterranean Basin has a long history, probably dating back to more than 6.000 years, when it started to spread from Eastern Mediterranean to the West (Thompson 2020) and slowly after 4000 years reached countries such as

Tunisia and Spain, when the humanity was starting to understand the benefits of the olive fruits (Loumou & Giourga 2003). Centuries ago, it is said that the first Levantine traders and then the Roman Empire spread the olive groves even at the North African and Southwest European countries (Ladisa & al. 2012). It should be mentioned that there is a debate concerning the migration history of olives, olive domestication and cultivar identity as several data suggest the repeated trails to cultivate wild olives in NW Africa, Spain and elsewhere (Meyer & al. 2012; Diez & al. 2015; Kaniewski & al. 2012). Concerning to Greece, Phoenicians are said to be the first merchants, who brought *Olea europaea* to the country, while the trade at the Aegean archipelago begun around 1000 BC (Terral & al. 2004).

Olea europaea var. *sylvestris* (Mill.) Lehr., the wild olive tree, is one of the most common trees occurring on the slopes and on the manmade cultivated terraces throughout of the Mediterranean (Loumou & Giourga 2003). Through the time, the domestication of wild olive tree has led to different cultivated varieties of olive trees and their huge expansion in many Mediterranean countries along with human activities (Besnard & al. 2001).

Olive groves represent a core feature of the Mediterranean environment and culture; human activities had a marked and long-standing impact on the biodiversity of olive groves (Dretakis & al. 2012). The significance of traditional farming practices on Mediterranean areas and among them on continental Greece and Greek islands for the conservation of plant diversity has been highlighted in different studies (Turland & al. 2004; Bergmeier & Strid 2014; Bergmeier & Meyer 2018). The recent intensification of the cultivation's management, namely the increased use of fertilizers and pesticides as well as the abandonment of cultivated areas induce a sharp decrease in biodiversity, leading to the dominance of a few ruderal plant taxa (Storkey & al. 2012; Solé-Senan & al. 2014; Storkey & Neve, 2018; Panitsa & al. 2020; Georgiadis & al. 2022,).

During the 20th century, intensified farming practices (e.g. heavy use of agrochemicals and fertilizers, mechanized cultivation techniques) induced the sudden and deliberate removement of local wild flora, replacing the traditional agricultural practices (Beaufoy 2001). Thus, the intensification of agriculture from the one side increases olive production, but at the same time it is included among the major threats of global biodiversity (Solomou & Sfougaris 2011).

Lesbos (Lesvos), one of the biggest islands of the Aegean area, was named the Olive Island (Elaion Nisos) due to the cultivation of olive groves on hilly and terraced surfaces (Loumou & Giourga 2003). Local olive groves cover an area of about 40,215.8 ha., i.e., nearly 41% of the island's cultivated land (Taxidis & al. 2015). The different management of olive groves includes organic olive groves, mostly occurring on terraced areas, as well as the conventional (= intensive) and abandoned ones, which are found mostly at hilly areas (Kizos & Koulouri 2005, 2006). On Lesbos, as elsewhere, most farmers use chemical plant control against alien species such as *Oxalis pes-caprae* L. (Petsikos & al. 2007).

In the framework of our project focused on assessing the plant diversity of Greek olive groves, the aim of this study was to investigate the impact of different management practices on the vascular plant diversity of olive groves of the island of Lesbos. With this aim, the authors investigated the differences in terms of plant diversity among organic, conventional, and abandoned olive groves and illustrate the plant traits revealing these differences.

Material and Methods

Study Area

Lesbos, the third largest island of Greece with an area of 1969 km^2, is located at the Northeastern Aegean area. The climate of Lesbos is typical Mediterranean and suitable for cultivation of olive trees. According to the data provided by the Hellenic Meteorological Agency for the time 1955-2010, it is characterized by short winters and dry hot summers with, about five to six drought months, maximum temperature in July (31ºC) and minimum in December (6.1ºC) while average monthly humidity is 56% for July and 73% for December. Local vascular flora counts more than 1550 plant taxa (Bazos 2005; Strid 2016). The dominant natural vegetation is dominated by phrygana, olive groves, pinewoods, and rather localised oak forests. The olive groves are located mainly in the southern and eastern part of the island. The olive groves examined in this study are close to the Natura 2000 site GR4110005, of Mount Olympus (https://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=GR4110005), (Fig. 1).

Most of the olive groves in the studied area are conventional (intensive), few are organic and even fewer and covering smaller surfaces are the abandoned ones. This pattern is due

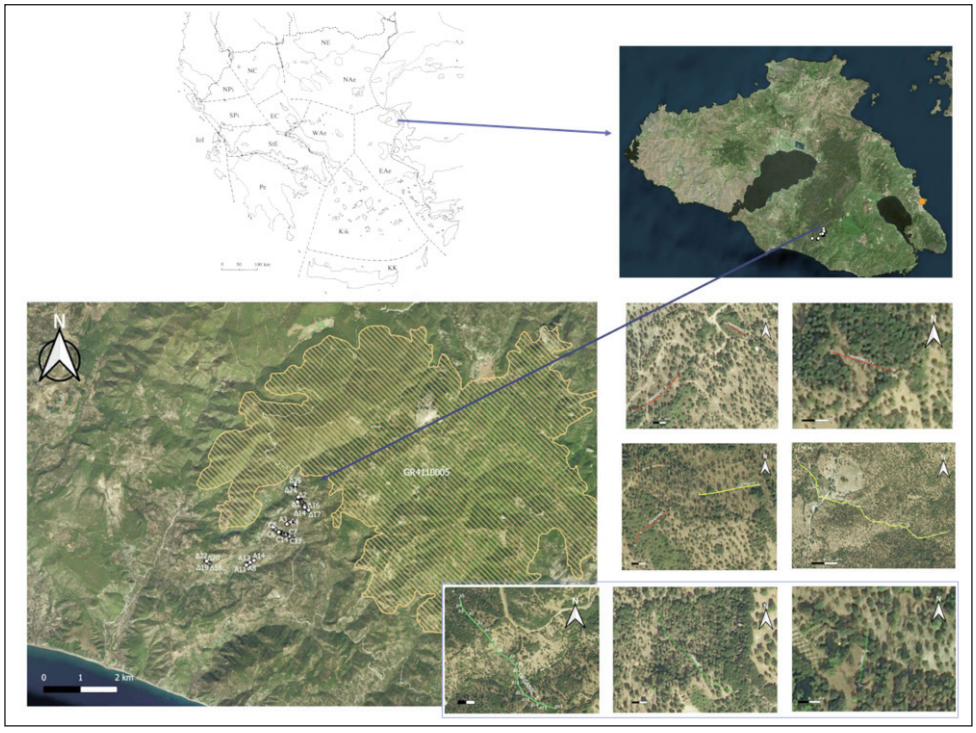

Fig. 1. Sampling area on Lesbos Island. A: Plots on abandoned olive groves (red transects), C: Plots on conventional olive groves (yellow transects) and D: Plots on organic olive groves (green transects).

to economic reasons since the local population is almost exclusively depended on olive grove cultivation and year after year this activity becomes more and more intense due to state subsidies for agricultural crops.

Sampling Methodology

Field work was carried out in the olive groves of the district of Ampeliko during spring 2020 (April and May) and repeated visits were carried out in all seasons of the year until December 2021 to record all the vascular flora. The sampling areas were selected in order to have a similar number of plots for each management typology, i.e., organic, conventional (intensive), and abandoned olive groves.

The floristic inventory has been carried out via transects of SW-NE direction at various elevations, and square sampling plots of 0.5 x 0.5 m and 25 m distance between them, all mapped using QGIS. The transects were not perfectly straight because of the irregular topography of the investigated (mostly terraced) areas, and the occurrence of fences which sometimes limited the accessibility to the groves. Plant communities' composition and structure of 65 sampling plots has been recorded using Braun-Blanquet method (1964). Of them, 25 were carried out on organic olive groves, 25 on conventional and 15 on abandoned olive groves. The mean elevation of the sampling areas was 373.2 m a.s.l. Data concerning vascular plants nomenclature and life forms (phanerophytes (P), chamaephytes (C), hemicryptophytes (H), geophytes (G) and therophytes (T)) follow Dimopoulos & al. (2013, 2016).

The free access statistical program Past (version 4.09, 2021) has been used to study α- and β- diversity as well as the species richness of the sampling plots. Shannon, Menhinick and Margalef diversity indices are simple species richness indices, characterized by the great advantage of ease calculation and Chao 1 is a simple estimator of the absolute number of species in an assemblage (Magurrán 2004). Concerning β- diversity, Whittaker, Cody as also Wilson & Schmida indices have been used since Whittaker's index is one of the simplest and the most effective measures of species richness, Cody's index provides a good measure on species spatial turnover and Wilson & Schmida's index includes the elements of species loss and gain. Chao's 2 and Jackknife 2 estimators use presence/absence data by taking account of the distribution of species among samples, while Jackknife 1 estimator uses the number of species occurring only in a single sample (Magurrán 2004).

Results

A total of more than 210 plant taxa belonging to 39 families and 135 genera occurs on the 65 sampling areas. More in detail, 145 taxa, belonging to 32 families and 104 genera, have been found in organic olive groves, 106 taxa (26 families, 78 genera) in conventional ones and 62 taxa (23 families, 53 genera) in abandoned groves (Table 1). Almost one third of the taxa have been observed growing only on organic olive groves, 19.5% only on conventional and 9.5% only on abandoned ones while only 10% of the taxa are present on all three types of olive groves, 28% are common among the organic and conventional olive groves, 17.7% among the organic and abandoned olive groves, and 12.4% among conventional and abandoned ones.

The species-richest families are: *Asteraceae*, *Poaceae*, *Fabaceae*, *Caryophyllaceae* and

Apiaceae. These families represent 15.6% of the families and count as much as 57.0% of the taxa found on organic olive groves, 19.2% of the families and 61.0% of the taxa of conventional ones and 21.7% of the families and 61.0% of the taxa on abandoned olive groves (Electronic Supplementary File 1: Table S1). Figure 2 shows the rate of taxa belonging to these families in the flora of organic, conventional, and abandoned olive groves. With 15 taxa, the genus *Trifolium* resulted to be the species-richest; interestingly enough, 73% of these taxa were present on organic, 60% on conventional and 33% on abandoned olive groves.

Concerning life-forms, therophytes predominate on all different managed olive groves and the percentage of therophytes and hemicryptophytes is higher in organic and conventional than in abandoned ones. Moreover, the percentage of phanerophytes and chamaephytes is higher on abandoned olive groves than in organic and conventional ones. Fig. 3 shows the different life-form spectra of the vascular flora of organic, conventional, and abandoned olive groves. Fig. 4 shows that the proportions of the families, genera, taxa, taxa of the richest families and life-forms recorded on organic olive groves are much higher than those on conventional and abandoned ones.

The maximum number of plant taxa per sampling plot for organic olive groves was 27,

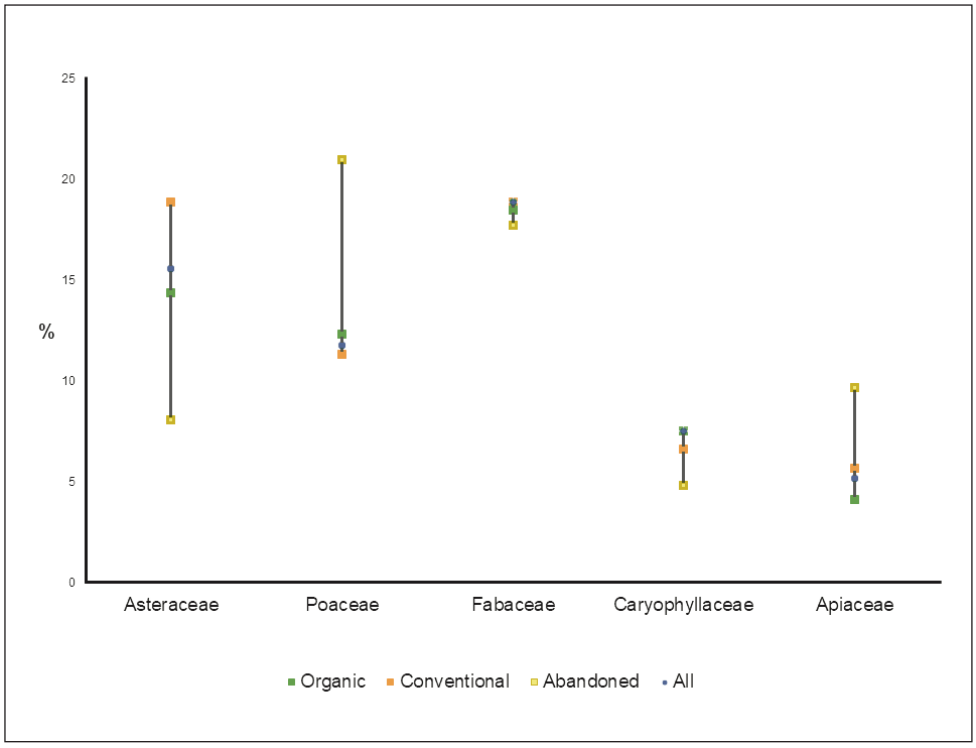

Fig. 2. Proportions of the taxa registered in organic, conventional, and abandoned olive groves, separately, belonging to the richest in species families of *Asteraceae*, *Poaceae*, *Fabaceae*, *Caryophyllaceae* and *Apiaceae*.

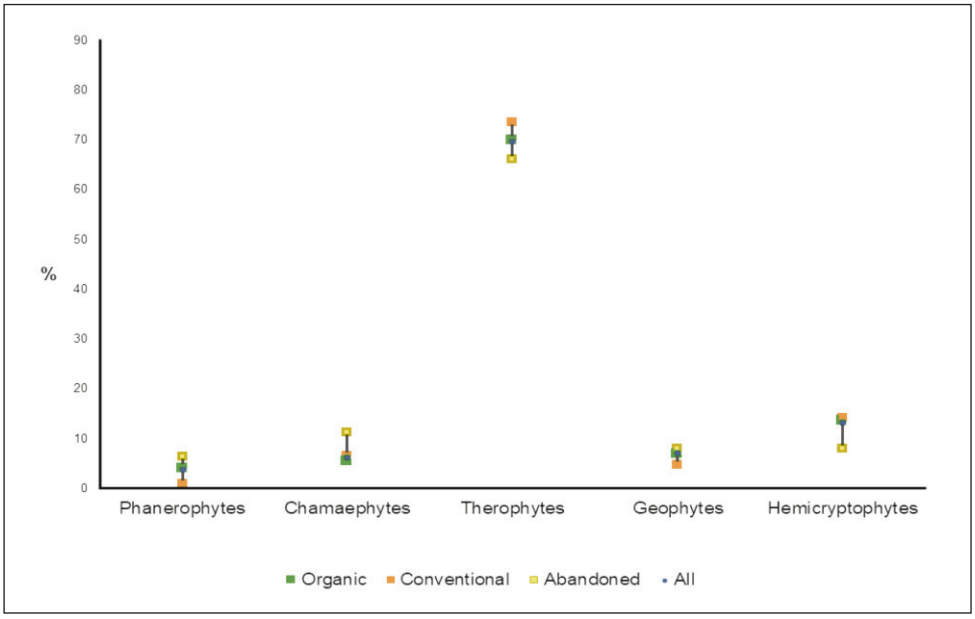

Fig. 3. Life-forms spectra concerning the vascular flora of organic, conventional, and abandoned olive groves.

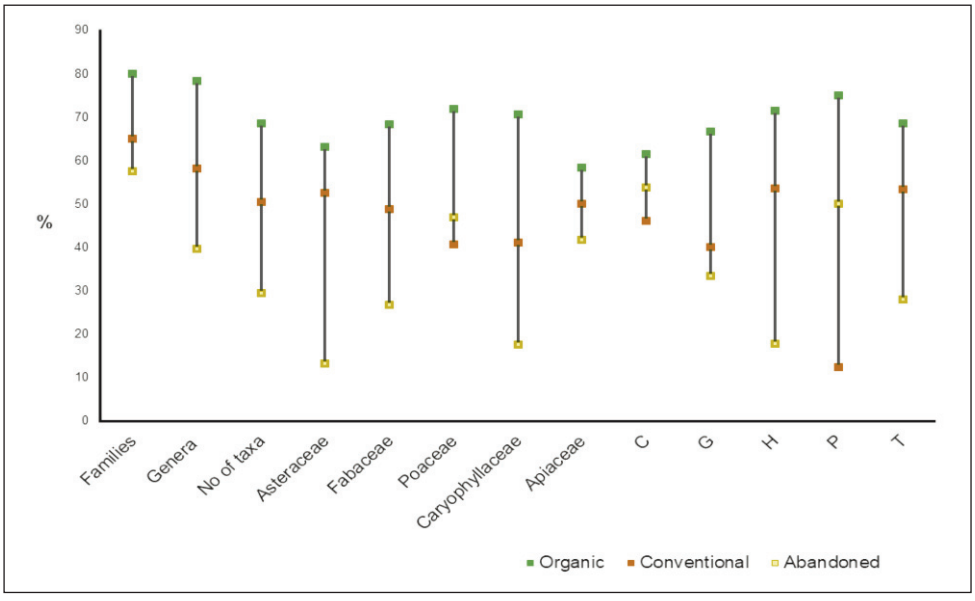

Fig. 4. Organic, conventional, and abandoned olive groves' proportions of the families, genera, number of taxa, richest families and life-forms on the total numbers recorded on all sampling areas.

with an average of 15 plant taxa, while for the conventional ones the maximum number of taxa was 17 with an average of 11 plant taxa; as for the abandoned olive groves, the highest number of plant taxa was 15 with an average value of 8 taxa.

The most common herbaceous species are: *Anthemis chia* L., *Trifolium campestre* Schreb., *Lagoecia cuminoides* L., *Crepis commutata* (Spreng.) Greuter, *Aegilops biuncialis* Vis., *Petrorhagia dubia* (Raf.) G. López & Romo, *Medicago orbicularis* (L.) Bartal., *Filago germanica* (L.) Huds. and *Dactylis glomerata* L., which were recorded on all three types of olive groves. The plants with the highest vegetation cover, mainly recorded on abandoned olive groves, are: *Cistus parviflorus* Lam., *Cistus criticus* L., *Phillyrea latifolia* L., *Sarcopoterium spinosum* (L.) Spach and *Lavandula stoechas* L.

Concerning α-diversity values, using the Shannon, Menhinick, Margalef, Fischer-alpha and Chao-1 indices, it was derived that a-diversity is much higher in the sampled organic olive groves than in the conventional and abandoned ones (Table 1). Additionally, values of all β-diversity indices among sampling plots of organic olive groves, are higher than those among plots of conventional and plots of abandoned ones. Values of β-diversity are much higher among plots of organic and abandoned olive groves, than among organic and conventional ones (Table 1). Quadrat richness calculations using four non-parametric species richness estimators and their standard deviations (St. dev.) also showed much higher values for organic olive groves than for conventional and abandoned ones (Table 2).

Discussion - Conclusions

Agricultural landscape dynamics in the Mediterranean have changed significantly the last 150 years and this is also the case for the Aegean Island of Lesbos (Kizos & Koulouri 2006). Local economic driving forces significantly changed Lesbos' olive agricultural landscape, mainly decreasing diversity of cultivated areas (Kizos & Koulouri 2005). The most common land use change is by far abandonment, which represents 96% of the olive land use changes (Kizos & Spilanis 2004) and significantly affects biodiversity (Myers &

Table 1. Values of α-diversity (**α**) and β-diversity (**β**, light grey cells) indices for sampling areas on organic, conventional, and abandoned olive groves and β-diversity (**β**, dark grey cells) indices between the pairs of Organic-Conventional, Organic -Abandoned and Conventional -Abandoned olive groves (grey cells).

	Index	Organic	Conventional	Abandoned	Organic-Conventional	Organic - Abandoned	Conventional -Abandoned
α	Shannon_H	4.916	4.412	3.954			
	Menhinick	9.265	6.732	6.498			
	Margalef	28.59	19.51	13.65			
	Chao-1	283.3	172.2	188.3			
β	Whittaker	11.888	9.223	9	13.106	17.947	15.658
	Wilson-Schmida	19.837	18.355	12.422	25.477	33.589	31.288
	Cody	255.5	197.5	79.5	298	351	285.5

Table 2. Quadrat richness: values of non-parametric species richness estimators and their standard deviations (St.dev.) for organic, conventional, and abandoned olive groves.

Organic			Conventional		Abandoned	
		St. dev		St. dev		St. dev
Chao 2:	278.082	32.448	165.12	20.252	187.956	53.202
Jackknife 1:	251.4	12.699	160.88	7.754	111.733	11.138
Jackknife 2:	305.105	NA	189.362	NA	147.762	NA

al. 2000; Haines-Young 2009).

The role and importance of traditional agriculture in the establishment and maintenance of biological diversity is variable and contentious (Siebert 2004). Our results showed that traditionally managed, organic olive groves are characterized by a high a-diversity, a rich and diverse flora, mainly dominated by therophytes and especially by annual leguminous species that are indicators of long-term but moderate human interference (Arianoutsou & Margaris 1981; Barbero & al. 1990; Panitsa & al. 2003). Local extensive olive groves managed by ploughing show a higher abundance and diversity of ruderal species and host many annual flowers supporting key plant-insect interactions which in turn provide important pollination services to the adjacent agricultural areas, playing a more important role with respect to the abandoned groves, where many perennial species, characteristic of the phrygana plant communities, dominate (Potts & al. 2006).

Conventional olive groves are also dominated by therophytes and have a poorer and rather ubiquitous vascular flora, while abandoned olive groves present a rather poor but diverse flora, mainly dominated by chamaephytes, hemicryptophytes and phanerophytes and to a lower proportion by annual plants, depending also on the time lapse after abandonment. The best adapted plant taxa, that are also found in most sampling areas are assigned to the families *Asteraceae*, *Poaceae* and *Fabaceae* as the members of these families occur in most of the sampling areas, and this was the case of other similar studies (Solomou & Sfougaris 2011). In fact, other research focused on the olive groves of Messenia (south Greece) and Magnesia (inner central Greece), revealed the same pattern, with the organic olive groves showing the highest diversity followed by the conventional and the abandoned groves with the therophytes as predominating life-form (Solomou & al. 2013; Kjellström 2014). Our results showed that most of the "characteristic therophytic and generally herbaceous indicator species" defined for the organic olive groves by Solomou & Sfougaris (2021) namely *Medicago lupulina* L.*, Hordeum bulbosum* L.*, Trifolium arvense* L.*, T. campestre* Schreb.*,* and *Anagallis arvensis* L., as well as *Sonchus oleraceus* L. for conventional olive groves, and additionally, the eurytrophic herbaceous taxa they mentioned for olive groves, have also been recorded in the sampling areas of Lesbos. Due to ongoing secondary succession processes, the vegetation of abandoned olive groves counts a higher number of woody species (mostly subshrubs and shrubs) which prevent the establishment and growth of perennial herbs under the low density of sunlight (Koulouri & Giourga 2007; Rühl & Pasta 2007; La Mantia & al. 2008; Maccherini

& al. 2013). The abandonment of traditional olive groves has a significant environmental impact inducing a fast and sharp shrinkage of plant diversity, an increase of erosion and fire risk, leading to major changes in the traditional (semi-natural + cultural) Mediterranean landscapes (Duarte & al. 2008).

As for α-diversity indices, our results show that all the indices are positively correlated with plant species richness, as is the case for Shannon diversity index (Petsikos & al. 2007; Solomou & Sfougaris 2011, 2021). This is also the case of β-diversity, where all indices used have higher values at the organic olive groves revealing the floristic differences among them and the much higher species richness and dissimilarity of the floristic composition at the organic sampling plots. These conclusions are corroborated by the values of non-parametric species richness estimators (quadrat richness) that are all much higher for sampling plots of organic olive groves if compared with the conventional and abandoned ones. Plant species diversity, total and mean number of species and consequently α- and β-diversity are usually higher in organic than in conventional farming systems, as was also shown by Solomou & Sfougaris (2011, 2021).

Concluding, the authors confirmed the results of studies carried out on the Greek mainland (Solomou & Sfougaris 2011, 2021; Kjellström 2014), showing that herbaceous plant species diversity could be the best indicator for environmental monitoring in olive groves. The indices of α- and β- diversity used in this study revealed significant differences among the different management systems of olive groves when considering these different aspects of diversity and could also be used for providing useful information about the impact of different farming practices in olive groves. Olive groves' landscapes have the potential for biodiversity conservation in the Mediterranean region, when they are adequately managed (Rey & al. 2019); since their vascular flora presents an exceptional resemblance to the flora of Mediterranean type ecosystems (Margaris & Mooney 1981), even in terms of functioning, cost-efficient condition, and ecosystem services (Loumou & Giourga 2003).

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