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Patterns of Soil Arthropod Community in Different Zones of Olive Cultivation in Crete, Greece

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Abstract

Olive production is a major agricultural activity for the Mediterranean basin. However, the knowledge on biodiversity patterns in olive agroecosystems is not sufficient known for important taxa like soil arthropods, in order to support sustainable farming approaches. In the present study, we hypothesised that different zones of olive cultivation, namely hills and plains, would be discriminated with regards to their effect on ground-dwelling arthropods, confirming previous research contacted in the same area of interest (Crete, Greece) but expanded in terms of production periods, study sites and by focusing on important taxa, like Coleoptera. The comparisons in terms of arthropod total abundance, richness and diversity, delivered statistically significant differences between orchards in hills and plains; arthropod diversity appeared to be seasonally higher in hills, although total abundance and richness were similar for both zones. Abundance of specific taxa were significantly different for three taxa in autumn, as well as for another four coleopteran families, while in spring difference appeared for six taxa, and six coleopteran families. The results were comparable with the previous study conducted in the area, indicating the discriminatory effect of the cultivation zones when arthropod biodiversity is considered. Further research would be required to confirm the interaction and the subsequent importance of agroecological attributes, like landscape, expecting to provide a biodiversity-based framework for olive farming.

Keywords

Olive Orchards, Farming, Agrobiodiversity, Agroecology

1. Introduction

Agricultural land already covers approximately 40% at global scale, while it hosts a plethora of species and habitats [1]. Consequently, agroecosystems and their biodiversity are regarded as facing serious threats, not only because of the implementation of intensive farming approaches [2], but also due to habitat fragmentation and homogenization of the agricultural landscape [3, 4]. Such negative impact, in turn, can generate loss of important agroecosystem services, e.g. biological pest control or soil fertility agents that could lead to the degradation of the quality and quantity of agricultural production.

The Mediterranean basin is a particular example of agricultural land use, where human intervention takes place for millennia [5], with olive groves being a dominant landscape feature cultivated in different pedoclimatic zones, predominantly hills or plains [6]. The olive agroecosystem frequently undergoes modifications driven by several types of agronomic practices [7], imposing a significant effect on several parts of biodiversity, especially ground-dwelling fauna [8, 9, 10]. The soil arthropod community is an important asset for the olive agroecosystem. They may deliver substantial agroecosystem services, functioning as pest control and nutrient cycling agents [11, 12, 10], while certain fractions of arthropod fauna, like Coleoptera, can become useful bioindicators, as they respond to ecosystem modifications due to external pressures [7].

Although olive production of major importance for several Mediterranean countries and territories, recognized as biodiversity hotspots, specialized studies on the biodiversity patterns in olive orchards are rather limited [13, 14, 10], especially in Greece. Indeed, patterns of biodiversity and ecological functioning in agroecosystems are not sufficiently known for several areas or taxa, in order to guide sustainable farming approaches [15]. Previously contacted research [10, 16] has provided clues that the different zones of olive cultivation, namely hills and plains, can be discriminated with regards to their agroecological features, such as biotic and abiotic factors, elevation and landscape attributes, when the effect on important fauna, like arthropods, is considered. Therefore, the zone of cultivation may correspond to diverse agricultural landscapes and distinguishable management approaches, with hills being regarded as less suitable for intensive farming practices and inputs, because of limitations generated by several terrain and pedoclimatic conditions [6, 17].

The present study was planned in order to confirm and expand previous findings [18, 10] on the patterns of ground-dwelling arthropod community in olive orchards, located at hills and plains. Consequently, the objective was set as to monitor the soil arthropod community, expanding the study sites and production periods, and focusing deeper on important taxa, such as Coleoptera, by hypothesizing that their abundance and diversity would be differentiated with regards to the zone of cultivation.

2. Methods

2.1 Study sites and sampling

The study took place in twelve olive orchards located in the area of Messara (35^{o} 01’N, 24^{o} 49’E), southern Crete, Greece, a representative olive production region. The orchards were selected on the basis of expanding previous research carried out in the area [19, 20, 18]. Accordingly, they were equally allocated in the two different zones of cultivation, i.e. hills and plains, differentiated upon elevation, terrain, abiotic (soil type and fertility, rainfall, temperature, humidity) as well as biotic environment (fauna and flora). Additionally, the intensity of management applied in the different zones is considered to be differentiated, as farming in hills is less suitable for intensive soil practices and inputs, such as irrigation, due the limitations of terrain and pedoclimatic conditions [6, 17]. All orchards were commercially managed for at least 30 years, planted with “Koroneiki” olive tree variety, one of the prevailing Greek olive cultivars. Their average size was 0.52 ha, ranging from 0.27 to 1.14 ha, considered typical for the area (Table 1). A total of 10 weekly measurements took place on the course of the study (autumn 2019 to spring 2020), including autumn and spring sampling, coinciding with the optimal arthropod activity in the olive agroecosystem.

Table 1. Attributes of olive orchards under study in the different zones of cultivation

Orchard Nr	Zone of cultivation	Area (ha)	Slope (%)	Year of plantation	Planted variety	Tree density (per ha)
1	hills	0.51	1.61	1995	Koroneiki	206
2	hills	0.33	1.54	1995	Koroneiki	198
3	hills	0.66	1.68	1992	Koroneiki	228
4	hills	0.29	1.52	1992	Koroneiki	205
5	plains	0.38	0	1980	Koroneiki	209
6	plains	0.28	0	1982	Koroneiki	211
7	hills	0.34	2.43	1990	Koroneiki	216
8	hills	0.27	1.34	1980	Koroneiki	220
9	plains	1.11	0	1991	Koroneiki	210
10	plains	0.54	0	1991	Koroneiki	227
11	plains	1.14	0	1993	Koroneiki	212
12	plains	0.45	0	1993	Koroneiki	219

2.2 Arthropod monitoring

Six monitoring stations per hectare were defined in the olive orchards, accomplished by means of pitfall traps (plastic, colorless cups, 7.5 cm of diameter and 11.5 cm of height) filled with propylene glycol. The traps were placed, achieving minimum terrain disturbance, and left on site for a period of 7 days, either under the tree canopy or between tree rows; in a distance of 1.5 m from the olive tree trunk, when under canopy, and 4 m when between tree rows. After each sampling, the arthropods were transported to the laboratory facilities in plastic bags, filtered and cleaned of debris and inorganic material and then examined by stereomicroscope (C-PS, Nikon).

Identification of the sampled arthropods was based on quantifiable morphological characteristics, taxonomized to the order level, besides Chilopoda and Diplopoda (to class level), as an appropriate approach for rapid biodiversity assessments [21]. Coleoptera were further classified at family level, due to their significance and potential role as bioindicators in the olive agroecosystem [7]. Families Scarabaeidae, Carabidae, Staphylinidae, Tenebrionidae, Silphidae, Cucujidae, Ptinidae, Curculionidae, Nitidulidae, Anthicidae, Buprestidae and Geotrypidae. Formicidae were counted separately due to their abundance. Chilopoda, Dermaptera, Diplopoda and Hymenoptera (besides Formicidae) were not included in tables due to their scarcity (less than 0.5%), while other not true ground-dwellers retrieved, such as Diptera, Lepidoptera and Mecoptera, were not considered.

2.3 Data analysis

The arthropods sample were described in terms of a) total taxa abundance (number of total catches per orchard surface); b) taxa richness (S); and c) diversity indices including the reverse Simpson's Index of diversity (1-D), a common but robust and meaningful descriptor [22] and the Pielou's Index (J), representing community's evenness. Both indices are characterized as especially useful for purposes of communities' comparison [23].

A univariate statistical analysis approach was used to compare the different zones of cultivation, except richness, in terms of the above measures, using SPSS 20.0® for Windows. The data were assessed for their normality by means of Shapiro-Wilk test ($p<0.05$) and were found to be not normally distributed, even after several transformations. Eventually, the Mann – Whitney non-parametric test was selected to assess the community's differences between the zones of cultivation, with a significance reported at the predefined levels of $p<0.05$ and $p<0.01$.

In order to represent visually the species abundance distribution (SAD) in the different zones of cultivation, rank abundance curves (Whittaker plots) were as also formulated as a common but robust informative method [22], for the purposes of the study.

3. Results and discussion

3.1 Total arthropod abundance and diversity

A total of 28,011 arthropods were captured during the whole study period, classified into 16 taxa (orders and classes), including twelve coleopteran families, all found in both zones of cultivation (Table 2). 14,223 individuals were collected in olive orchards located in the hills, representing 50.82% of the total catches, and another 13,788 in the plains, representing 49.18%. The difference of total catches between zones was not statistically significant (Table 3), also shown in the boxplots generated (Figure 1), accumulatively representing the arthropod abundance for the whole study period. Additionally, the highest catches appeared in spring's sampling (73.52%) and then autumn (26.48%).

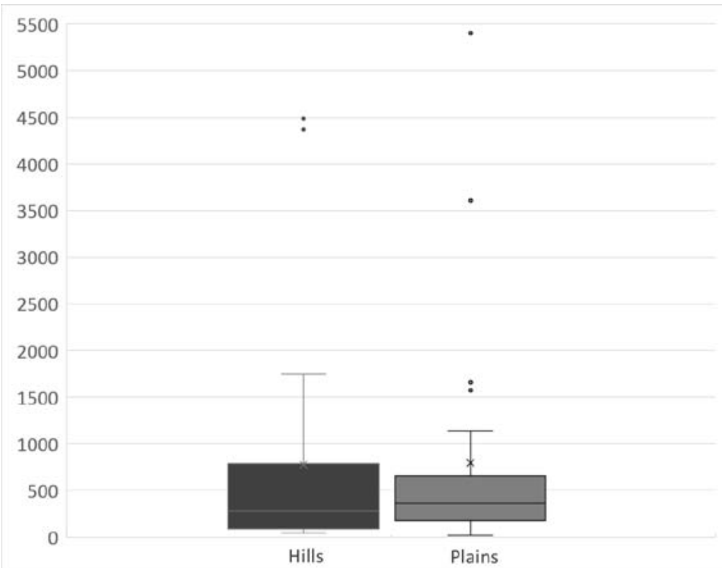

Figure 1. Boxplots of ground-dwelling arthropod abundance in different zones of cultivation, presenting medians and quartiles, accumulatively for the whole study period.

Table 2. Abundance per hectare of ground-dwelling arthropods, total abundance, richness and diversity indices, for each cultivation zone and the seasonal (autumn, spring) as well as whole monitoring period of the study

Monitoring season	autumn		spring		Σ	
Zone of cultivation	Hills	Plains	Hills	Plains	Hills	Plains
Acarina	179	166	406	388	585	554
Araneae	419	554	1,044	583	1,463	1,137
Coleoptera	588	776	3,899	4,607	4,487	5,384
Scarabeidae	187	28	616	179	803	187
Carabidae	160	267	143	401	304	668
Staphylinidae	102	213	352	384	454	597
Tenebrionidae	71	138	1,677	1,438	1,749	1,576
Silphidae	15	30	203	469	218	499
Cucujidae	5	8	64	171	69	179
Ptinidae	8	18	34	190	42	208
Curculionidae	17	33	309	476	326	509
Nitidulidae	9	35	112	345	121	380
Anthicidae	2	5	108	210	109	214
Buprestidae	4	6	76	106	81	112
Geotrypidae	7	14	204	240	212	254
Collembola	533	302	199	258	733	560
Dictyoptera	42	16	72	153	113	169
Formicidae	1309	1185	3,065	2,424	4,374	3,610
Hemipt./Heteropt.	5	4	52	13	57	18
Other Hemiptera	37	25	213	62	251	87
Isopoda	275	361	414	1,300	689	1,661
Opiliones	286	140	961	205	1,247	345
Orthoptera	28	41	43	38	71	80
Thysanura	34	29	17	22	51	51
Total abundance	3,736	3,659	10,385	10,055	14,223	13,788
S	15	15	16	16	16	16
1-D	0.737	0.747	0.628	0.576	0.682	0.661
J	0.782	0.777	0.616	0.556	0.699	0.667

S: Richness; 1-D: Reverse Simpson's index; J: Pielou's index; Σ, sum abundance for the whole monitoring period. Other taxa counted and not presented due to scarcity (<0.5%): Chilopoda, Dermaptera, Diplopoda and hymenoptera (besides Formicidae).

In the Whittaker plots (Figure 2), both zones of cultivation presented similar shallow slopes in all seasons, as an indication of relatively high evenness. The slope in autumn was relatively steeper than in spring and in summer, due to higher taxa dominance, in accordance with previous results [18]. A minor seasonal difference also appears for species richness (1 species) in the autumn's sampling period (see also S values in Table 2).

Statistically significant differences were presented for both diversity indices of Simpson and Pielou's in spring, being higher for orchards located in hills (Table 3). The above results are comparable to previous findings in the study area [18, 10] as similar patterns appeared regarding the total abundance, the SAD among monitoring seasons and the significance of difference between the zones of cultivation, while they also present similarities when compared to other studies [24, 8].

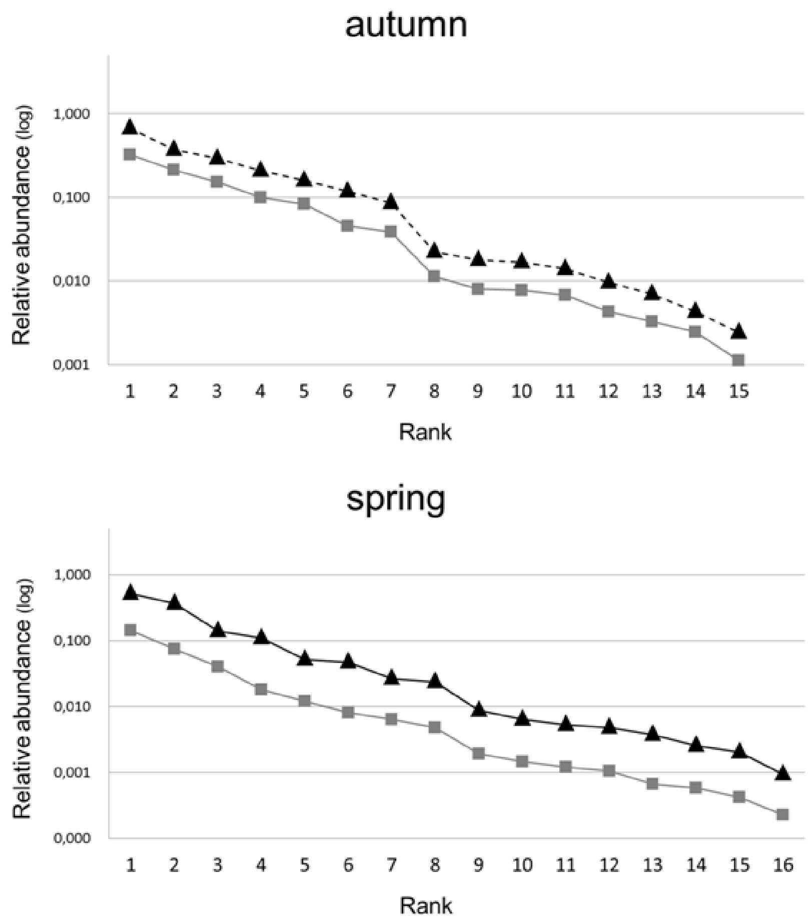

Figure 2. Whittaker plots (Rank abundance curves) of the arthropod community in hills (▲) and plains (■) for autumn and spring measurements.

Table 3. Results of the Mann–Whitney test, including U and Z, as applied to the comparison between two zones of cultivation (hills and plains) in seasonal samplings (autumn and spring) for the study period

Taxon	autumn		spring	
	U	Z	U	Z
Acari	74.5	0.134	52.0	-2.281
Araneae	107.4*	2.201	62.0	-0.433
Coleoptera	92.0*	1.278	115.0**	2.682
Scarabaeidae	32.5**	-2.328	9.0**	-3.456
Carabidae	106.0*	2.167	131.0**	3.599
Staphylinidae	109.0*	2.344	88.0	0.918
Tenebrionidae	110.5*	2.234	99.0	1.523
Silphidae	92.0	1.234	81.5	0.488
Cucujidae	47.5	-1.647	2.0*	-4.088
Ptinidae	86.0	0.799	24.0*	-2.832
Curculionidae	77.5	0.378	67.0	-0.187
Nitidulidae	102.0	1.789	22.5*	-2.884
Anthicidae	64.0	-0.465	11.5**	-3.456

Buprestidae	51.0	-1.243	72.0	0.181
Geotrypidae	104.0	1.895	97.0	1.467
Collembola	89.0	1.343	74.0	0.478
Dictyoptera	81.0	1.294	79.0	0.378
Formicidae	5.0	-1.111	41.0*	-1.978
Heteroptera	52.0	-1.215	13.5**	-3.383
Other Hemiptera	59.0	-0.784	31.0*	-2.458
Isopoda	79.0	0.334	11.0**	-3.221
Opiliones	21.5**	-2.980	2.0**	-4.101
Orthoptera	90.0	1.136	80.0	0.449
Thysanura	72.0	0.897	67.5	-1.588
Total abundance	51.0	-1.221	73.0	0.158
1-D	103.0	1.821	14.5**	-3.232
J	70.5	-0.044	21.0**	-3.322

* p<0.05, **p<0.01: Predetermined levels of significance used.

3.2 Specific taxa

The dominating taxa across the whole monitoring period were Coleoptera, accounting for 35.31%, Formicidae (28.50%), Aranae (9.28%), Isopoda (8.39%), Opiliones (5.68%), Collembola (4.62%) and Acarina (4.07%), followed by other Hemiptera, Dictyoptera, Orthoptera, Thysanura, Heteroptera, Chilopoda, Dermaptera, Diplopoda and hymenoptera, accumulatively accounting for the rest 4.4%. Within order Coleoptera, the most abundant families were Tenebrioniade (29.16%), Carabidae (12.37%), Staphylinidae (11.04%), Curculionidae (9.42%), Silphidae (9.23%), Nitidulidae (7.03%), Geotrypidae (4.70%), Anthicidae (3.97%), Ptinidae (3.85%) and Scarabeidae (3.84%), followed by the less abundant families of Cucujidae (3.32%) and Buprestidae (2.08%). Differences of ranking appeared when comparing to other studies in olive agroecosystems elsewhere, with regards to main arthropods' dominance [25, 24, 8, 10]. Nevertheless, the main arthropods collected the olive agroecosystems in the present study are considered to be within the group of the most abundant and frequently appearing taxa in similar research conducted globally [16].

Statistically significant differences between zones of cultivation regarding the specific arthropod abundance, were presented for 3 taxa in autumn, of which two (Aranae and Coleoptera) were higher in the plains and one (Opiliones) in hills, and 6 taxa in spring; 2 higher in the plains (Coleoptera and Isopoda) and 4 in the hills (Formicidae, Hemiptera/Heteroptera, other Hemiptera and Opiliones). The seasonal differentiation between zones of cultivation was again comparable with the previous study conducted in the area of interest [18] and elsewhere [24, 25], indicating spring as a peak season for soil arthropod abundance and in terms of differences.

For Coleopteran families, there were 4 statistically significant differences in autumn (3 higher in plains, 1 in hills) and 6 significant differences in spring (5 in plains and 1 in hills) (Table 3). Both the abundance and diversity of the monitored taxa followed similar patterns, as in previous research in the study area [18, 10]. Minor differences appeared with regard to the ranking of most abundant taxa, with Isopoda being ranked as most abundant than Collembola and Opiliones, as previously found in the above mentioned studies [18, 10].

4. Conclusion

The present study provided significant data on the ground-dwelling arthropod community of the olive agroecosystem confirming previous findings in the study area, by expanding the monitoring period and monitoring sites. The similarity of patterns with regards to the abundance, diversity and richness of arthropods, appearing when different zones of cultivation were compared, indicate a rather robust proof of the discriminatory effect that these zones possess, when specific and important fractions of biodiversity are considered. Likewise, this becomes a potential evidence of the importance of agroecological factors integrated within the different zones of cultivation, such as climatic conditions, soil attributes, farming practices and landscape composition and configuration.

Considering the above, a further, more detailed, analysis of the data generated would be required in order to assess and confirm the interactions of the several biotic and abiotic factors to specific taxa of interest for the olive production, such as functional arthropods delivering important agroecosystem services, with special attention given to factors less considered in previous research frameworks, like landscape attributes. The expected outcome would contribute significantly towards a providing biodiversity-based framework for sustainable olive farming, by integrating agroecological guidelines and principles.

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References

[1] Martin, L. J., Blossey, B., & Ellis, E. (2012). Mapping where ecologists work: biases in the global distribution of terrestrial ecological observations. *Frontiers in Ecology and the Environment*, 10(4), 195-201. https://doi.org/10.1890/110154.

[2] Biaggini, M., Consorti, R., Dapporto, L., Dellacasa, M., Paggetti, E., & Corti, C. (2007). The taxonomic level order as a possible tool for rapid assessment of Arthropod diversity in agricultural landscapes. *Agriculture, Ecosystems & Environment*, 122(2), 183-191. https://doi.org/10.1016/j.agee.2006.12.032.

[3] Bailey, D., Schmidt-Entling, M. H., Eberhart, P., Herrmann, J. D., Hofer, G., Kormann, U., & Herzog, F. (2010). Effects of habitat amount and isolation on biodiversity in fragmented traditional orchards. *Journal of applied ecology*, 47(5), 1003-1013. https://doi.org/10.1111/j.1365-2664.2010.01858.x.

[4] Kormann, U., Rösch, V., Batáry, P., Tscharntke, T., Orci, K. M., Samu, F., & Scherber, C. (2015). Local and landscape management drive trait-mediated biodiversity of nine taxa on small grassland fragments. *Diversity and Distributions*, 21(10), 1204-1217. https://doi.org/10.1111/ddi.12324.

[5] Blondel, J., Aronson, J., Bodiou, J. Y., & Boeuf, G. (2010). The Mediterranean region: biological diversity in space and time. Oxford University Press.

[6] Kabourakis, E. (1996). "Prototyping and dissemination of ecological olive production systems: A methodology for designing and a first step towards validation and dissemination of prototype ecological olive production systems (EOPS) in Crete". Published PhD thesis. Wageningen Agricultural University. The Netherlands.

[7] Pizzolotto, R., Mazzei, A., Bonacci, T., Scalercio, S., Iannotta, N., & Brandmayr, P. (2018). Ground beetles in Mediterranean olive agroecosystems: Their significance and functional role as bioindicators (Coleoptera, Carabidae). PloS one, 13(3), e0194551. https://doi.org/10.1371/journal.pone.0194551.

[8] Santos, S., Cabanas, J., & Pereira J. (2007). Abundance and diversity of soil arthropods in olive grove ecosystem (Portugal): Effect of pitfall trap type. *European Journal of Soil Biology*, 43(2), 77-83. https://doi.org/10.1016/j.ejsobi.2006.10.001.

[9] Cotes, B., Campos, M., Pascual, F., García, P. A., Ruano, F. (2010). Comparing taxonomic levels of epigeal insects under different farming systems in Andalusian olive agroecosystems. *Applied Soil Ecology*, 44(3), 228-236. https://doi.org/10.1016/j.apsoil.2009.12.011.

[10] Gkisakis, V., Volakakis, N., Kollaros, D., Bàrberi, P., & Kabourakis, E. M. (2016). Soil arthropod community in the olive agroecosystem: Determined by environment and farming practices in different management systems and agroecological zones. *Agriculture, Ecosystems & Environment*, 218, 178-189. http://dx.doi.org/10.1016/j.agee.2015.11.026.

[11] Orsini, M. M., Daane, K. M., Sime, K. R., Nelson, E. H. (2007). Mortality of olive fruit fly pupae in California. *Biocontrol Science and Technology*, 17, 797-807. https://doi.org/10.1080/09583150701527359.

[12] Daane, K. M., Johnson, M. W. (2010). Olive fruit fly: Managing an ancient pest in modern times. Annual Review of Entomology, 55, 151-169. https://doi.org/10.1146/annurev.ento.54.110807.090553.

[13] Solomou, A., & Sfougaris, A. (2011). Comparing conventional and organic olive groves in central Greece: plant and bird diversity and abundance. *Renewable Agriculture and Food Systems*, 297-316. https://www.jstor.org/stable/44490643.

[14] Gonçalves, M. F., & Pereira, J. A. (2012). Abundance and Diversity of Soil Arthropods in the Olive Grove Ecosystem. *Journal of Insect Science*, 12(20), 1-14. https://doi.org/10.1673/031.012.2001.

[15] Stoate, C., Baldi, A., Beja, P., Boatman, N. D., Herzon, I., Van Doorn, A., ... & Ramwell, C. (2009). Ecological impacts of early 21st century agricultural change in Europe—a review. *Journal of environmental management*, 91(1), 22-46. https://doi.org/10.1016/j.jenvman.2009.07.005.

[16] Gkisakis, V. D., Volakakis, N. G., & Kabourakis, E. M. (2020). Agroecological zones as an important driver of canopy arthropod community in olive agroecosystems. *Biological Control*, 149, 104319. https://doi.org/10.1016/j.biocontrol.2020.104319.

[17] Metzidakis, I., A. Martinez-Vilela, Castro Nieto, G., & Basso, B. (2008). Intensive olive orchards on sloping land: Good water and pest management are essential. *Journal of Environmental Management*, 89, 120-128. https://doi.org/10.1016/j.jenvman.2007.04.028.

[18] Gkisakis, V. D., Kollaros, D., Bàrberi, P., Livieratos, I. C., & Kabourakis, E. M. (2015). Soil arthropod diversity in organic,

integrated, and conventional olive orchards and different agroecological zones in Crete, Greece. *Agroecology and Sustainable Food Systems*, 39(3), 276-294. https://doi.org/10.1080/21683565.2014.967440.

[19] Kabourakis, E. M. (1999). Code of practices for ecological olive production systems. *Olivae*, **77**, 46-55.

[20] Volakakis, N. G., Eyre, M. D., & Kabourakis, E. M. (2012). Olive fly Bactrocera oleae (Diptera, Tephritidae) activity and fruit infestation under mass trapping in an organic table olive orchard in Crete, Greece. *Journal of Sustainable Agriculture*, 36(6), 683-698. https://doi.org/10.1080/10440046.2012.672377.

[21] Cotes, B., Campos, M., García, P. A., Pascual, F., & Ruano, F. (2011). Testing the suitability of insect orders as indicators for olive farming systems. *Agricultural and Forest Entomology*, 13(4), 357-364. https://doi.org/10.1111/j.1461-9563.2011.00526.x.

[22] Magurran, A. E. (2004). Measuring Biological Diversity. Blackwell, Oxford.

[23] McGill, B. J., Etienne, R. S., Gray, J. S., Alonso, D., Anderson, M. J., Benecha, H. K., Dornelas, M., Enquist, B. J., Green, J., He, F., Hurlbert, A., Magurran, A. E., Marquet, P. A., Maurer, B. A., Ostling, A., Soykan, C. U., Ugland, K., & White, E. (2007). Species abundance distributions: moving beyond single prediction theories to integration within an ecological framework. *Ecology Letters*, 10(10), 995-1015. https://doi.org/10.1111/j.1461-0248.2007.01094.x.

[24] Ruano, F., Lozano, C., Garcia, P., Peña, A., Tinaut, A., Pascual, F., & Campos, M. (2004). Use of arthropods for the evaluation of the olive orchard management regimes. *Agricultural and Forest Entomology*, 6(2), 111-120. https://doi.org/10.1111/j.1461-9555.2004.00210.x.

[25] Morris, T. I., Campos, M., Kidd, N. A. C., Jervis, M. A., & Symondson, W. O. C. (1999). Dynamics of the predatory arthropod community in Spanish olive grove. *Agriculture and Forest Entomology*, 1, 219-228. https://doi.org/10.1046/j.1461-9563.1999.00030.x.