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# BIRD, HERBACEOUS AND WOODY PLANT ASSEMBLAGES IN THE NATURAL AND AGRICULTURE MEDITERRANEAN-TYPE ECOSYSTEMS: THE ROLE OF AGRICULTURE AND ENVIRONMENTAL FACTORS

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## ABSTRACT

Importance of olive groves (OG) and natural ecosystems in the Mediterranean is contrasting with low number of the studies of their biodiversity. In order to manage these systems in an environmentally friendly way, more knowledge of the factors affecting the biodiversity is required. The aim of this study was to evaluated relative importance of the agricultural and environmental factors on species richness estimated in the chosen plots by line point method (herbaceous plants), plots of 100 m$^2$ (woody plants) and point count method (breeding birds). Multi model inference approach showed: a) positive relationship between: a1) field size, manure application, soil organic matter and yield and species richness of herbaceous plants; a2) ─ in organic OG ─ soil organic matter and woody plant species richness, and field size, soil pH, grass cutting and bird species richness; a3) ─ in the conventional OG ─ herbaceous plant species richness and the amount inorganic K application, and b) negative association between: b1) ─ in the conventional OG ─ field size and herbicide application, and b2) bird species richness and soil erosion and herbicide applications.

**Keywords:** Biodiversity, conventional farming, sustainable management, abandonment, maquis.

## 1. INTRODUCTION

The conservation of biodiversity depends on the sufficient knowledge of the spatial distribution and abundance of species (Schrag et al., 2009). The observed decline in farmland biodiversity in the last years has been attributed to changing farming practices (Donald et al., 2001). The spatial scales of the inflicted changes and the particularity of their effects differ according to different biological groups, agricultural and environmental factors and farming systems (Guerrero et al., 2010). In a practice, detailed information about the relationship between biodiversity and particular management factors are not available for many crops. This is, unfortunately, also true for the olive groves, despite their economic importance. The deficit of valid and implicit information in this subject constrains the design of qualified recommendations for agri-environmental programs aiming to protect biodiversity (Kleijn and Sutherland, 2003, Guerrero et al., 2010).

A strong relationship between environmental factors and species richness and abundance in floristic and faunal communities is known. However, this relationship differs among organizational levels and spatial scales (Grand and Cushman, 2003). Therefore, the power and impacts of the environmental factors will determine the composition of biotic communities and depends on species, ecological characteristics and their functional structure (Schmitzberger et al., 2005).

In the case of agro ecosystems the intensity of agriculture has led to soil erosion, overexploitation of water resources, water pollution, biodiversity loss and deterioration in traditional agricultural landscapes (Gómez Calero, 2009) and to widespread decline of biodiversity in cropland measured across many different taxa (Benton et al., 2003).

At the same time, the abandonment of agricultural land, resulting from economic and social changes, is one of the most serious land use changes recorded in the Mediterranean basin. Additionally, it had a particular impact on soil erosion, while changes in agricultural practices and soil resources management influence fundamental ecosystem processes which in turn have an impact on ecosystem functions. In Greece, it is possible to compare and contrast the role of abandoned and extensively cultivated olive groves (Koulouri and Giourga, 2007).

Hence, research data on the influence of different management factors on selected biological groups (herbaceous and woody plants, and birds), in an economically important agro-ecosystem of the Mediterranean regions such as olive groves (organic, conventional and abandoned management system), and natural ecosystem is limited so far.

This study aimed at investigating the effects of agricultural and environmental factors on species richness variability of herbaceous and woody plants, and bird communities, of some aspects of agricultural intensification (conventional management system), alternative sustainable agriculture schemes (organic management system) and land use changes (abandoned) in olive grove ecosystems of central Greece and their comparison to those of neighbouring natural ecosystems (maquis) as reference sites. The specific objectives of the study were: (1) to assess the influence of management systems on herbaceous and woody plants, and bird species richness, and (2) to test the relative predictive importance of each agricultural and environmental factor for taxa species richness within the olive grove management systems and in maquis.

## 2. STUDY AREA

The study was conducted in a 312 km$^2$ area of western Magnesia Prefecture in central Greece (39º03'12.05"N, 22º57'11.84"E) (Fig. 1). The study area is included in the *Quercetalia ilicis* vegetation zone, and *Quercion ilicis* and *Oleo-Ceratonion* subzones. The main rock substrate of the study area is metamorphic schist (IDPRA, 2002). The typical Mediterranean climate is characterized by relatively cold and wet winters and hot and dry summers. The mean annual temperature in the studied region is 16.8 °C, with the warm maxima in July and with the cold minima in January and February. The mean annual rainfall reaches at 490 mm (Fig. 2) (National Meteorological Service of Greece).

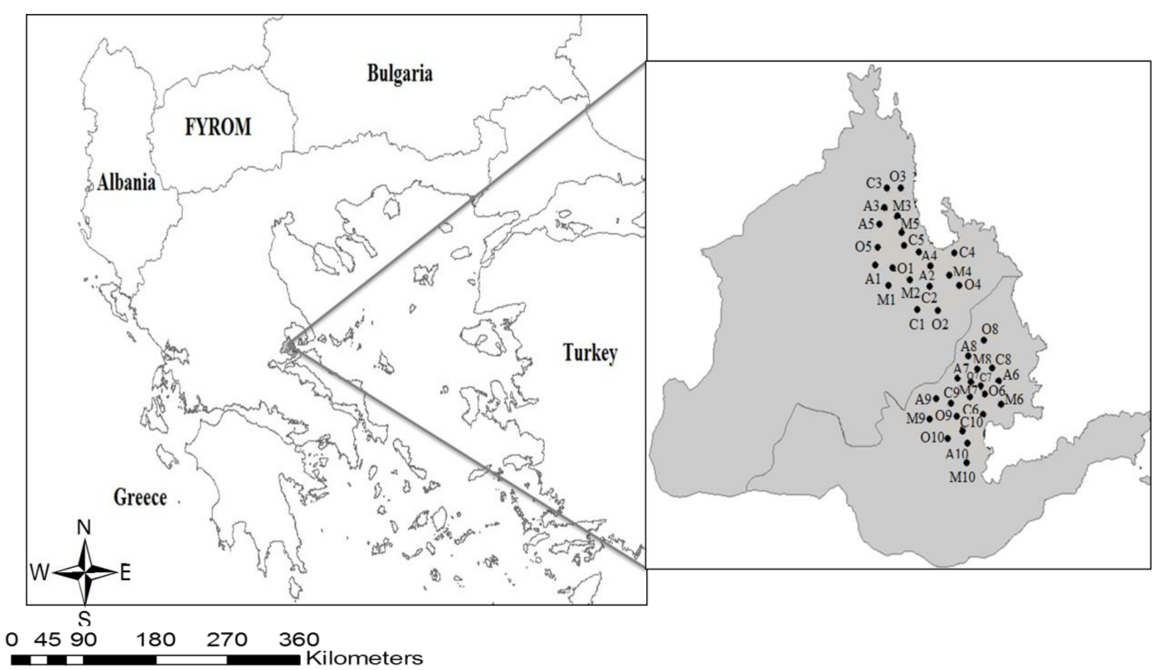


**Fig. 1 Study area (western Magnesia, central Greece)**

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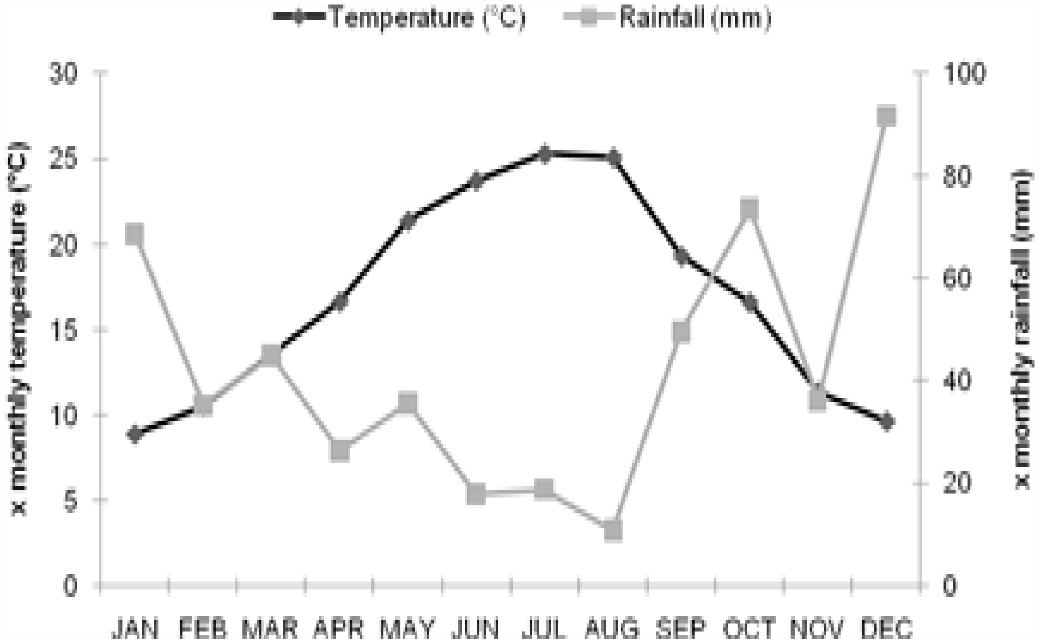


**Fig. 2 Ombrothermic diagram of the study area for the period 1956-2010 (National Meteorological Service of Greece 2011).**

## 3. MATERIAL AND METHODS

### 3.1 Sampling sites

Field work was conducted in spring 2009 and 2010. A set of 30 olive grove farms [10 organic (O1-O10), 10 conventional (C1-C10), 10 abandoned (A1-A10)] and 10 natural ecosystems (maquis) (M1-M10) was randomly selected. The farms were selected in a way to reduce the effect of 'exterior' factors and allow a better comparison among the three farm management systems and maquis ecosystems. The sampled farms were at least 200 m away from each other and the sampling points 100 m away from the farm edges to avoid edge effects. The characteristics and management practices applied to the selected farms are presented in Table 1.

**Table 1. General characteristics and applied management practices to the olive grove farms surveyed.**

| | Organic olive groves | Conventional olive groves | Abandoned olive groves | Maquis |
|---|---|---|---|---|
| Average field size (ha) | 13.83 | 15.5 | 11.3 | 38.5 |
| Average number of olive trees per hectare | 200 | 200 | 200 | |
| Age of olive groves | ~150-170 | ~150-170 | ~150-170 | |
| Variety of olive groves | Amfissa | Amfissa | Amfissa | |
| Years of enrolment | 1997 | | | |
| Manure (kg per tree) | 50 | | | |
| Inorganic fertilizer N (kg per tree) | | 1.5-2 | | |
| Inorganic fertilizer K (kg per tree) | | 1.5-2 | | |
| Organic fertilizer K (kg per tree) | 2-3 | | | |
| Weed control | Grass cutting | Herbicide | | |
| Irrigation | No | No | | |

## 3.2 Sampling procedures

### 3.2.1 Herbaceous and woody plants, and birds censuses

We evaluated groups of taxa that exhibit different taxonomic, functional, and spatial aspects of local and regional biodiversity (Pearson,1995). Based on criteria, such as wide range of species, sufficient distinction as to their size, mobility and ecological requirements we chose to test suitability to estimate species richness herbaceous and woody plants, and birds. They are known to be good indicators of environmental change and they have well-known life histories so that changes in their diversity can be related to observed changes in the environment (Noss, 1990). Species richness was selected as an expression of biodiversity due to it common use to evaluate and monitor the health of ecosystems and as a tool for conservation planning (Hoffmann, 2010). Also, species richness was chosen because of its simplicity and sensitivity to processes acting at different spatial scales on species differing in size and mobility (Guerrero et al., 2010).

Herbaceous plant species were surveyed in May 2009 and 2010. Sampling of herbaceous species was carried out by the Line Point Method (Heady et al., 1959). Woody vegetation was inventoried during the same period as herbaceous vegetation in randomly selected sampling plots of 100 $m^2$ (10 m x 10 m) (Koutsidou, 1995).

The avifauna was surveyed from early May until middle of June so as to include the breeding period (. Jobin et al., 2001). For bird counting the point count method was followed (Bibby et al., 1992). The counts were carried out from early morning till 10.30 a.m. and only during the days without present rain or wind (Collin et al., 1992). Only breeding pairs, in each plot of 50m radius were recorded by two observers. Each count lasted for 10 minutes (Foschi and Gellini, 1983).

**Table 2. Sampling points and traps in different management systems and maquis.**

| | **Organic olive groves** | **Conventional olive groves** | **Abandoned olive groves** | **Maquis** |
|---|---|---|---|---|
| Herbaceous plant | 140 | 140 | 130 | 140 |
| Woody plant | 140 | 140 | 130 | 140 |
| Breeding bird | 140 | 140 | 130 | 140 |

### 3.2.2 Agricultural and environmental factors

In most cases the factor "management system" which contributes much to the variation of diversity is already known or information is easily available (Döring et al., 2003). Consequently, no agricultural and environmental indicators are needed to indicate the management system, but agricultural and environmental indicators are useful to predict the rest of variability of diversity within the olive grove management system. Hence, data on 18 common agricultural factors were gathered at the end of the crop season through questionnaires distributed to farmers owning each of the sampled fields: field size (ha), application of herbicide, grass cutting, application of nitrogen (N) (inorganic fertilizer), potassium (K) (inorganic fertilizer), potassium (K) (organic fertilizer), manure ($t.ha^{-1}$) and yield ($t.ha^{-1}$).

Because soil characteristics can influence herbaceous and woody plants, and birds distribution (Young and Young, 2001), some important soil characteristics were measured. In each farm, five soil samples were randomly taken (0 to 30cm depth) and mixed to obtain one representative sample. Analyses included estimation of soil pH (McLean, 1982), amount of organic matter (Nelson and Sommers, 1982) and level of moisture per sample (Page et al., 1982). Additionally, the presence of soil erosion, occurrence of plant litter and ecosystem type were recorded visually. The measured air humidity (%) and temperature (°C) were estimated with a Thermo-Hygrometer (Digital Thermo-Hygrometer, TFA). The topographic characteristics of the plots, altitude and slope were recorded using a global positioning system (GPS; e-Trex Vista, Garmin Co. Ltd) and a clinometer (Suunto Tandem) (Table 3).

**Table 3. The average values and their standard deviations (SD) of the chosen agricultural and environmental factors, in olive groves under different management systems and, for comparison, in maquis ecosystems.**

| Factors | Description of factors | Organic olive groves (Mean±SD) | Conventional olive groves (Mean±SD) | Abandoned olive groves (Mean±SD) | Maquis ecosystem (Mean±SD) |
|---|---|---|---|---|---|
| ***Agricultural factors*** | | | | | |
| Field size (ha) | Scale | 13.83 ±10,37 | 15.5±10.92 | 11.3±7.66 | 38.5±25.94 |
| [a]Herbicide use | Nominal | 0 | 1 | 0 | 0 |
| [b]Grass cutting | Nominal | 1 | 0 | 0 | 0 |
| Manure (kg $ha^{-1}$) | Scale | 9.60±0.51 | 0 | 0 | 0 |
| [c]Inorganic N (kg $ha^{-1}$) | Scale | 0 | 117.00±13.70 | 0 | 0 |
| [d]Inorganic K (kg $ha^{-1}$) | Scale | 0 | 120.00±25.29 | 0 | 0 |
| [e]Organic (kg $ha^{-1}$) | Scale | 81.00±14.49 | 0 | 0 | 0 |
| Yield (t $ha^{-1}$) | Scale | 8.83±0.47 | 9.51±0.74 | 0 | 0 |
| ***Environmental factors*** | | | | | |
| Air humidity (%) | Scale | 63.85±6.25 | 59.11±12.37 | 69.01±8.65 | 62.70±6.94 |
| Air temperature (°C) | Scale | 18.66±1.47 | 20.02±2.06 | 17.49±1.77 | 19.41±2.99 |
| Soil pH | Scale | 7.01±1.14 | 6.77±0.75 | 6.87±0.82 | 7.18±0.60 |
| Soil organic matter (%) | Scale | 3.32±1.30 | 1.97±0.74 | 1.14±0.37 | 4.31±1.25 |
| Soil moisture | Scale | 18.70±1.53 | 16.56±1.77 | 14.72±1.20 | 17.28±2.15 |
| [f]Plant litter | Nominal | 0 | 0 | 1 | 2 |
| [g]Soil erosion | Nominal | 0 | 1 | 0 | 0 |
| Altitude (m) | Scale | 80.39±51.71 | 62.84±47.20 | 140.40±51.19 | 112.29±62.80 |
| Slope (%) | Scale | 29.65±21.05 | 23.96±17.97 | 60.03±16.88 | 54.41±12.02 |
| [h]Ecosystem type | Nominal | 0 | 0 | 0 | 1 |

[a]Herbicide: 0: no, 1: yes, [b]grass cuttings, [c]Inorganic N (kg.ha$^{-1}$): Ammonium nitrate ($NH_4NO_3$), [d]Inorganic K (kg.ha$^{-1}$): Potassium sulfate ($K_2SO_4$), [e]Organic K (kg.ha$^{-1}$): Potassium sulfate with magnesium (K+S KALI GmbH), [f]Plant litter: 0:low, 1: moderate, 2: high, [g]Soil erosion: 0: no, 1: yes, [h]Ecosystem type: 0: olive groves, 1: maquis.

### 3.3 Statistical analysis

If the yearly trends provided similar results in a specific parameter then, in order to increase the robustness and generality of the results, data from all two years were analyzed together (Fried et al., 2008). Data were evaluated for normality and homogeneity by Kolmogorov-Smirnov and Shapiro-Wilks tests. If needed, they were transformed using $\log_{10}(x+1)$ to meet normality assumptions (Zar, 1999). The influence of management systems on herbaceous and woody plant, and bird species richness and their comparison to maquis ecosystems was evaluated by using of the General Linear Model (GLM, Type III Sum of Squares) (One-way ANOVA) (Zar, 1999). Pair-wise comparisons of samples were carried out with the Tukey HSD post hoc test. The above mentioned analyses were accomplished with PASW software, v.18 (PASW, 2009).

GLM were applied to analyze separately each taxon and management system. The agricultural and environmental factors explaining most variance (McCullagh and Nelder, 1989). In each case, stepwise selection was used, aiming to construct a good model with as many explanatory variables and having true predictive power for the response. The model optimization was achieved by the dropping and adding of variables in a model according to their significance in the presence of the other variables. The Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) (Bio et al., 2002) were used to select the best models. All variables remaining in the final models had probability values $P<0.05$ (Cameron and Windmeijer, 1997).

## 4. RESULTS

### 4.1 Influence of management systems on species richness

Herbaceous and woody plants, and birds were widespread in the study area. A total number of 78 and 18, and 31 species of herbaceous and woody plant, and bird species were recorded in organic olive groves respectively. In the conventional olive groves the recorded herbaceous and woody plant, and bird assemblages included 47 and 17, and 21 species respectively. Also, diverse herbaceous and woody plants, and birds assemblages were recorded, including 62 and 25, and 28 species in abandoned olive groves. In the case of maquis, a total of 34 and 28, and 33, herbaceous and woody plants, and birds species were identified (Appendices I,II,III,IV,V). Nine out of recorded 28 bird species are included in the Birds Directive (2009/147/EC) Annexes (Annex I: Nightjar, Cetti´s warbler, Common Cuckoo, Olive-tree Warbler, Red-backed Shrike, Lesser Grey Shrike and Black Wheatear - Annex II/2: European Turtle Dove and Common Blackbird).

Regarding the mean species richness per farm of herbaceous and woody plants, and birds, the significant differences among the different management systems (organic, conventional, and abandoned) of olive groves and maquis were detected (Table 4). More specifically, species richness of herbaceous plants was found to be supported by the organic system and by the abandoned olive groves. Finally, bird species richness were found higher in the organic and abandoned olive groves, and maquis than in the conventional ones (Table 4).

**Table 4. Mean species richness (msr/farm) values for herbaceous and woody plants, and birds in olive groves under different management systems (organic, conventional, abandoned) and maquis ecosystems.**

| Species richness | Organic olive groves (Mean±SD) | Conventional olive groves (Mean±SD) | Abandoned olive groves (Mean±SD) | Maquis ecosystems (Mean±SD) | $R^2$ | F | p |
|---|---|---|---|---|---|---|---|
| Herbaceous plants | 28.65±3.27a* | 16.80±4.47c | 20.85±3.04b | 10.05±1.73d | 0.82 | 56.21 | 0.00 |
| Woody Plants | 11.90±0.80c | 7.25±1.82d | 15.60±1.19b | 21.10±1.96a | 0.92 | 147.36 | 0.00 |
| Birds | 14.75±3.65a | 7.70±2.69b | 11.05±2.71ab | 13.75±4.15a | 0.57 | 8.80 | 0.00 |

* different letters (row) mean statistically significant differences at significance level $p < 0.05$.

### 4.2 Influence of agricultural and environmental factors on herbaceous and woody plants, and bird richness in olive grove management systems

Generalized linear models results are summarized in Table 5. More important, field size, manure application, soil organic matter and yield had a positive influence on herbaceous plant species richness and similarly soil organic matter on woody plant species richness, and field size, soil pH and grass cutter on bird species richness in organic olive groves.

In the conventional olive groves, herbaceous plant species richness was positively associated with inorganic K application and negatively by field size and herbicide application. Woody plant species richness was positively influenced by the applied inorganic N and K. Bird species richness was negatively influenced by soil erosion and herbicide application. In abandoned olive groves, presence of higher soil moisture had a positive influence on herbaceous plant species richness, soil organic matter on woody plant species richness but field size had a negative influence on bird species richness. The plant litter had a positive effect on the herbaceous plant, and bird species richness and soil organic matter on woody plant species richness in maquis.

**Table 5. Model fit diagnostics and final significant terms for generalized linear models of taxa species richness in several olive grove management systems.**

| Management systems | Dependent parameters | df | Adjusted $R^2$ | Likelihood Ratio Chi- | Sig. | AIC | BIC | Model (Equation) |
|---|---|---|---|---|---|---|---|---|
| Organic olive groves | | | | | | | | |
| | Herbaceous plants | 4 | 0.69 | 17.86 | 0.00 | 45.94 | 45.75 | 3.43+0.25(fieldsize)+4.42(manure)+2.04(organic matter) +0.85(yield) |
| | Woody plants | 1 | 0.47 | 7.63 | 0.00 | 23.03 | 23.94 | 10.52+0.47(organic matter) |
| | Birds | 3 | 0.60 | 13,29 | 0.00 | 50.40 | 51.94 | 29.90+2.12(pH)+0.17(field size)+3.00(grass cutter) |
| Conventional olive groves | | | | | | | | |
| | Herbaceous plants | 3 | 0.78 | 19.57 | 0.00 | 46.95 | 48.46 | 15.14-0.04(field size)-2.44(herbicide) +0.08(inorganic K) |
| | Woody plants | 2 | 0.80 | 18.66 | 0.00 | 28.83 | 30.04 | 10.61+0.15(inorganic N)+0.01(inorganic K) |
| | Birds | 2 | 0.94 | 31.83 | 0.00 | 23.84 | 25.05 | 15.56-2.80(herbicide)-0.42(soil erosion) |
| Abandoned olive groves | | | | | | | | |
| | Herbaceous plants | 1 | 0.83 | 19.36 | 0.00 | 36.94 | 37.85 | 13.00+2.26(soil moisture) |
| | Woody plants | 1 | 0.51 | 8.38 | 0.00 | 29.42 | 30.33 | 12.38+1.95(organic matter) |
| | Birds | 1 | 0.47 | 5.92 | 0.01 | 46.03 | 46.94 | 13.50+0.22(field size) |
| Maquis | | | | | | | | |
| | Herbaceous plants | 1 | 0.69 | 13.14 | 0.00 | 32.08 | 32.99 | 6.83+1.05(plant litter) |
| | Woody plants | 1 | 0.47 | 7.56 | 0.00 | 38.32 | 39.23 | 16.39+0.94(organic matter) |
| | Birds | 1 | 0.84 | 19.97 | 0.00 | 41.36 | 42.26 | 5.70+2.66(plant litter) |

# 5. DISCUSSION

## 5.1 Management systems and species richness

Our study evaluated the effect of management systems on herbaceous and woody plant, and bird species richness in olive groves and maquis. The compared management systems differently influence species richness. Specifically, the results support the positive effects of organic farming on species richness in herbaceous plant and bird communities. In our opinion the best explanation provides the well-known organic farming theory (Ministry of Rural Development and Food, 2011) stating that the organically managed fields offer more abundant and the more diverse food resources and can accommodate more species (Hyvönen et al., 2003). The exclusion of the pesticides and synthetic fertilizers, and the use of animal manure and organic fertilizers provide a base to increase soil fertility and the chance for biodiversity to thrive in our organic olive groves. Positive influences of organic farming on the flora and fauna species richness and generally on preservation of wildlife species have been well documented for arable crops as summarized by Henderson et al. (2009) and Hole (2002) in their literature reviews.

In our study area, the conventional farming did not promoted-local herbaceous and woody plant, and bird species richness in olive groves. The use of herbicide and insecticide by olive growers was probably the main cause of the reduced establishment of flora and fauna species richness under conventional farming in olive groves. Also, they may cause habitat loss as a consequence the reduction of the food resources having a negative impact in the productivity of individual species or communities, with intense influences that are likely to disperse along food chains. It is known that the agricultural intensification, including conventional use of pesticides and synthetic-chemical fertilizers has resulted in biodiversity losses worldwide (Letourneau and Bothwell, 2008). Several pesticides are toxic to wildlife but they can also have important influences by reducing the community of herbaceous plants, insects and invertebrates which are basic food sources for birds in arable cultivation.

In the area studied, it seems that small-scale landscapes play an important role enhancing at least the animal species richness. This is probably related to behavioral responses and individual decisions of the specific biological groups. Contradictorily, Bengtsson et al. (2005) suggested that positive effects of organic farming on species richness of birds, insects and plants can be expected in large-scale landscapes consisting of numerous crop types. However, Weibull et al. (2003) did not find any effects of farming systems on plant species richness. Freemark and Kirk (2001) and Beecher et al. (2002) have reported higher bird species richness and abundance in organic than in non-organic farms as a result of increased complexity of food web in the landscape. Increased ground beetle activity in organic farms, compared to the conventional ones, has been reported by Pfiffner and Niggli (1996) and Brose (2003), while Purtauf et al. (2005) did not find any differences between organic and conventional farms.

Maquis represented reference habitat in our study. Maquis is less influenced by human interventions, confirming the hypothesis of supporting higher diversity of birds woody plants than cultivated systems such as conventional olive groves in our study area. Another potential explanation for greater species richness in the less disturbed habitats, such as natural habitat, than in more disturbed habitats is that in frequently or intensely disturbed environments, community composition cannot progress beyond early initial stages. This frequent 'resetting of the successional clock' in areas of high disturbance results in environments that enhance early successional species, while disfavoring later successional species (Büchs et al., 2003). If the disturbance is sufficiently serious and frequent, it could possibly exclude all but the most wild of taxa, leading to overall lower species richness (Pérez-Bote and Romero, 2012). According to Eyhorn et al. (2002), natural ecosystems can be a model for organic farming systems which tend to follow the laws of nature.

Surprisingly, in our study the herbaceous plant species richness was not enhanced by the dense maquis. This is possibly attributed to limited light availability as a result of increasing canopy cover of maquis, due to the competition, which is an important factor for the herbaceous plant communities. Also, other factors, such as topography (e.g. slope) and water availability may explain this result. To be more specific, during rainfall events, maquis which have steeper slopes present more infiltration excess runoff, so there is less water infiltration. Consequently, moisture levels seem to be higher in not so steep slopes such as in the olive groves of our study area. A second possible interpretation is that drainage take place at a faster rate in higher slopes resulting in lower moisture levels which remain after precipitation events (Qiu et al., 2001). Studies have shown that canopy structure is an important factor in determining the composition of understory plant communities in forests(Bainbridge and Strong, 2005).

In contrast to the study conducted by McLaughlin and Mineau (1995) our study concluded that herbaceous and woody plant, and bird species richness were enhanced by the abandoned olive groves. The above result probably related to succession stages of herbaceous and woody plant development in abandoned olive groves. According to Houssard et al. (1980) changes in plant species composition during succession are defined as the result of a dynamic balance between colonization, persistence and extinction of species. Also, other possible explanation is that abandoned ecosystems with low to moderate modification/intensification (such as native vegetation) are likely to have greater habitat complexity, due in part to less exposure to intensive and uniform management than many cropping systems. More complex habitat composition and structure may allow greater access to a wider range of alternative food resources (Langellotto and Denno, 2004), thus supporting more omnivorous such as carabids, herbivorous and saprophagous such as tenebrionids (Pérez-Bote and Romero, 2012) and they can also have indirect effects on birds. Therefore, plant diversity has long been recognized as an important factor determining the diversity of organisms at higher trophic levels.

**5.2 Processes for enhancing or diminishing biodiversity in the olive grove management systems**

The role of yield was particularly significant in this study. Yield is usually taken as a definite correlate of agricultural intensification (Green et al., 2005). In contrast to other study, our study showed a positive explanatory power of yield for herbaceous plant variation in organic olive groves. This may be due, in addition to the farming practices applied, to the soil conditions configured under this system. Another possible explanation is that herbaceous plants aid beneficial soil animals to be active at the soil surface, inserting their nutrient feces and acting as biological control factors against several insect pests, promoting the yield in organic olive groves. Also, as their roots penetrate deep in the soil they can amass trace elements, as well as other various elements, from the subsoil and transfer them to the soil surface. These elements become ready for use to olive groves through the herbaceous plants death and decomposition.

In contrast to the studies by Belfrage et al. (2005) and Marini et al. (2009) our study showed a positive influence of field size on the herbaceous plant and carabid species richness in organic olive groves and for bird species richness both in organic and abandoned olive groves. The relation between field size and the above biological groups probably reflects the response of the above biological groups to the spatial landscape heterogeneity (more noncropped habitat, field margins, hedges and woodlands), within the largest organic and abandoned olive groves, which provides benefits for different taxa in our study area. This fact may also follow the rule of species-area relation, as larger areas tend to contain larger numbers of species (Preston, 1962).

Interestingly, field size negatively influenced herbaceous plant species richness in conventional olive groves. The expected negative influence of herbicide application by farmers on herbaceous plant species richness in the spring was confirmed, possibly due to their high accumulation in largest field size of conventional olive groves. It’s worth pointing out here the ability of herbaceous plants to rely on both their seed bank and immigrating seeds from field boundaries (Romero et al., 2008). However, it is known that in any given landscape the mean field size increases usually lead to diminishing the density of field boundaries. It is, therefore, obvious that decreased neighborhood effects could be found behind the detected negative associations because of the fact that smaller number of species emigrate from surrounding habitats appropriate for annual and ruderal plants (Gabriel et al., 2005).

Moreover, relevant at the field level, the expected negative influence of herbicide applications on herbaceous plants was confirmed. Similarly, herbicide use has negative impacts on bird species richness and that may be due to toxicity, habitat changes and the decreases in abundance of several species on which birds rely for food or refuge in conventional olive groves.

In contrast to the studies by Cook et al. (2007) and Latty et al. (2006), our study highlighted that in organic olive groves, manure application was testified profitable predictor of herbaceous plant species richness, while organic matter was proved useful predictor of herbaceous and woody plant species richness. It may be attributed to manure and organic K contribution to soil fertility by adding organic matter and essential and trace nutrients which feed and favor the biological communities (Cook et al., 2007). Another possible reason is that manure contains relatively low concentrations of organic acids which affect directly and indirectly both flora and fauna community. Moreover, Pleasant and Schlater (1994) have reported that organic fertilization can increase the diversity of herbaceous plant community by introducing additional species. Yang et al. (2009) found that some soil parameters, such as soil organic matter, are related to wildlife species diversity.

Additionally, soil organic matter positively influenced woody plant species richness in abandoned olive groves and maquis. As mentioned above, the organic matter does not add any "new' plant nutrients but releases nutrients in a plant available form through the decomposition process (Lickacz and Penny, 2001). Several studies have documented that environmental variables, such as soil organic matter, may control plant species distribution and composition (Jafarian Jeloudar et al., 2010).

Interestingly, plant litter positively influenced herbaceous plant, and bird species richness in maquis. This striking result probably follows the bottom - up food web theory that predicts the increase of plant litter would in turn increase abundance (so species richness would increase) of species in all trophic level linked to the basal resources (Oksanen et al., 1981).

In addition, inorganic fertilizers are designed to supply plants all the nutrients such as Nitrogen, Phosphorous and Potassium that they need. Therefore, herbaceous and woody plant species richness were favoured by the application of inorganic fertilizer in conventional olive groves.

Our results highlight that soil erosion negatively influenced bird species richness in conventional olive groves. It is supposed that soil erosion has an indirect negative effect on breeding bird species richness due to its negative impacts on soil organisms and plants which form the basis of their diet. Hence, vegetation is the main component of ecosystem biomass and provides the resources needed by animals and microbes (Pimentel and Kounang, 1998). According to Majule

(2003) soil erosion tends to remove the fertility topsoil that is vital for the growth of different plant species.

Another important factor that determines the bird species richness in the organic olive groves is soil pH and grass cutter application. This may be due to that agro ecosystems with high soil pH usually contain more calcium-rich food items (seeds, insects, snail shells, eggshells, bone and calcareous grit) available for birds reproduction. This is in accordance with Pabian and Brittingham (2007) study which refer that birds require large amounts of calcium to reproduce and raise young in forests. Also, Simkiss (1967) found that the decreased availability of calcium could reduce reproductive output, or may be able to prevent ovulation. Moreover, herbaceous cutting with grass cutting may allow on birds to have easier access to prey in organic olive groves in our study area. Deacon and Rochard (2000) refer that the height of vegetation influences birds ability to detect food such as earthworms and other soil invertebrates, and to locate predators.

In our study area, soil moisture positively influenced herbaceous plant species richness in abandoned olive groves. A possible explanation is that high vegetation cover decreases the light and this leads to increasing soil moisture in abandoned olive groves. Soil moisture is an important factor which favours herbaceous plant growth, but herbaceous plant species richness is most affected by conditions which influence soil moisture. Furthermore, the well-known structural heterogeneity hypothesis (Murdoch et al., 1972) would be the simplest explanation which declares that higher structural heterogeneity might intensify higher trophic levels and this supports more potential niches for a functionally diverse fauna. Therefore, the trees provide an environment which is enriched with litter in abandoned olive groves.

## 6. CONCLUSIONS

Our study evidenced the high effectiveness of organic farming system in olive groves in terms of biodiversity enhancement. The results showed the importance of the factor "management system" on local herbaceous plant, and bird species richness. More specifically, there was a trend for increasing species richness of the specific biological groups (birds) in organic olive groves simulating that of neighbouring maquis ecosystems. Similarly, herbaceous and woody plant species richness were favoured by organic and abandoned olive groves.

Sensibly, several agricultural and environmental factors contributing to explaining variability in species richness of three biological groups in each management system. Specifically, field size, manure application, soil organic matter and yield were proved positive indicators of herbaceous plant species richness and accordingly the same applies to soil organic matter of the woody plant species richness, field size, soil pH and grass cutter of the bird species richness in organic olive groves. In the conventional olive groves, herbaceous plant species richness were positively associated with inorganic K application and negatively by field size and herbicide application. Woody plant species richness were positively influenced by the applied inorganic N and K. Bird species richness was negatively influenced by soil erosion and herbicide application. In abandoned olive groves, soil moisture served as positive indicator of herbaceous plant species richness, soil organic matter on woody plant species richness whereas field size was proved negative predictor of bird species richness. It is expected that the predictive power of any indicator can be altered due to intensity of agriculture, but the adoption of organic management system may secure the delay of loss of sensitive biodiversity indicators.

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## APPENDICES

Appendix. **I.** Presence (+) of the herbaceous plant species in the olive groves under different management system and maquis.

| **Family** | **Species** | **Organic olive groves** | **Conventional olive groves** | **Abandoned olive groves** | **Maquis** |
|---|---|---|---|---|---|
| Poaceae | *Aegilops ovata* | + | | | + |
| | *Aegilops geniculata* | + | + | + | |
| | *Aira elegantissima* | + | + | + | |
| | *Briza maxima* | + | + | + | |
| | *Bromus tectorum* | + | + | + | |
| | *Cynosurus echinatus* | + | | | |
| | *Dactylis glomerata* | + | | + | |
| | *Gaudinia fragilis* | + | | + | |
| | *Hordeum bulbosum* | + | + | + | |
| | *Hordeum murinum* | + | + | + | |
| | *Lagurus ovatus* | + | | | |
| | *Lolium perenne* | + | + | + | |
| | *Piptatherum miliaceum* | + | + | + | + |
| | Setaria verticillata | + | + | + | + |
| | *Sorghum halepense* | + | + | | |
| | *Avena barbata* | + | + | + | + |
| Asteraceae | *Anthemis arvensis* | + | + | + | + |
| | *Carduus pycnocephalus* | + | | | |
| | *Chrysanthemum segetum* | + | + | + | |
| | *Crepis rubra* | + | | + | + |
| | *Crupina crupinastrum* | + | + | + | |
| | *Onopordum acanthium* | + | | | |

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| | | | | | |
|---|---|---|---|---|---|
| | *Onopordum illyricum* | + | | | + |
| | *Onopordum tauricum* | + | | | |
| | *Matricaria chamomilla* | + | + | + | + |
| | *Leontodon tuberosus* | + | + | | + |
| | *Sonchus arvensis* | + | + | + | |
| | *Xanthium spinosum* | + | | | |
| Fabaceae | *Medicago lupulina* | + | + | + | |
| | *Trifolium arvense* | + | + | + | + |
| | *Trifolium campestre* | + | + | + | |
| Brassicaceae | *Raphanus raphanistrum* | + | + | + | + |
| | *Rapistrum rugosum* | + | | + | |
| Brassicacae | *Parietaria officinalis* | + | | + | |
| | *Sinapis arvensis* | + | | + | |
| Malvaceae | *Alcea biennis* | + | | | |
| | *Lavatera arborea* | + | | + | |
| | *Malva sylvestris* | + | + | + | |
| Araceae | *Arisarum vulgare* | + | | + | + |
| | *Dracunculus vulgaris* | + | | + | + |
| Asphodelaceae | *Asphodeline lutea* | + | | | |
| Apiaceae | *Daucus carota* | + | + | + | + |
| | *Eryngium campestre* | + | + | + | + |
| | *Orlaya daucoides* | + | | + | |
| | *Orlaya grandiflora* | + | | | |
| | *Oenanthe pimpinelloides* | + | | + | |
| | *Pallenis spinosa* | + | + | + | |
| | *Smyrnium rotundifolium* | + | | | |
| | *Tordylium apulum* | + | + | + | + |
| | *Ferulago nodosa* | + | | + | + |

| | | | | | |
|---|---|---|---|---|---|
| Convolvulaceae | *Convolvulus althaeoides* | + | + | + | + |
| | *Convolvulus elegantissimus* | + | + | + | |
| Papaveraceae | *Fumaria officinalis* | + | + | + | + |
| | *Fumaria capreolata* | + | | + | |
| | *Papaver nigrotinctum* | + | + | + | + |
| | *Papaver rhoeas* | + | + | + | + |
| Caryophylaceae | *Silene cretica* | + | | + | + |
| Orchidaceae | *Anacamptis pyramidalis* | + | + | | |
| Primulaceae | *Anagallis arvensis* | + | + | + | + |
| | *Cyclamen graecum* | + | + | + | + |
| Scrophulariaceae | *Bellardia trixago* | + | + | | |
| | *Orobanche purpurea* | + | | + | |
| | *Verbascum undulatum* | + | | + | |
| Leguminosae | *Onobrychis caput-galli* | + | | + | |
| | *Scorpiurus muricatus* | + | + | + | |
| Campanulaceae | *Campanula spathulata* | | | + | + |
| Geraniaceae | *Erodium cicutarium* | + | + | + | + |
| | *Geranium robertianum* | + | + | + | + |
| Liliaceae | *Muscari comosum* | + | + | + | + |
| Cistaceae | *Cistus incanus* | + | | + | |
| | *Tuberaria guttata* | + | + | + | + |
| Lamiaceae | *Salvia verbenaca* | + | + | | |
| | *Salvia viridis* | + | + | + | + |
| | *Satureja nervosa* | + | | | |
| Cyperaceae | *Carex flacca* | + | | + | + |
| Boraginaceae | *Echium plantagineum* | | + | + | + |
| Dipsacaceae | *Knautia integrifolia* | + | + | | |

| | | | | | |
|---|---|---|---|---|---|
| | *Scabiosa stellata* | + | | | |
| Euphorbiaceae | *Euphorbia helioscopia* | + | + | + | + |
| Chenopodiaceae | *Chenopodium album* | | + | + | |
| Rubiaceae | *Galium aparine* | + | | | |
| Iridaceae | *Gladiolus italicus* | + | | | |
| Zygophyllaceae | *Tribulus terrestris* | + | | + | |

Appendix II. **Presence (+) of the woody plant species in the olive groves under different management system and maquis.**

| **Species** | **Family** | **Organic olive groves** | **Conventional olive groves** | **Abandoned olive groves** | **Maquis** |
|---|---|---|---|---|---|
| *Arbutus adrachne* | Ericaceae | | | | + |
| *Arbutus unedo* | Ericaceae | | | + | + |
| *Asparagus officinalis* | Asparagaceae | + | + | + | + |
| *Calycotome villosa* | Leguminosae | | | + | + |
| *Cercis siliquastrum* | Leguminosae | + | + | + | + |
| *Cistus incanus* | Cistaceae | | | + | + |
| *Equisetum arvense* | Equisetaceae | | | | + |
| *Erica manipuliflora* | Ericaceae | + | + | + | + |
| *Ficus carica* | Moraceae | | | + | |
| *Fumana thymifolia* | Cistaceae | | | + | + |
| *Inula helenium* | Asteraceae | + | + | + | + |
| *Juniperus oxycedrus* | Cupressaceae | | + | + | + |
| *Juniperus phoenicea* | Cupressaceae | + | + | + | + |
| *Myrtus communis* | Myrtaceae | | | + | + |
| *Olea europaea* | Oleaceae | + | + | + | |
| *Olea. europaea var. sylvestris* | Oleaceae | + | + | + | + |
| *Paliurus spina-cristi* | Rhamnaceae | + | + | + | + |

| | | | | | |
|---|---|---|---|---|---|
| *Phlomis fruticosa* | Lamiaceae | + | + | | + |
| *Pistacia lentiscus* | Anacardiaceae | + | + | + | + |
| *Pistacia terebinthus* | Anacardiaceae | | | + | + |
| *Pyrus amygdaliformis* | Rosaceae | + | + | + | + |
| *Pyrus communis* | Rosaceae | + | + | | |
| *Quercus coccifera* | Fagaceae | + | + | + | + |
| *Quercus pubescens* | Fagaceae | | | | + |
| *Rhamnus alaternus* | Rhamnaceae | | | + | + |
| *Rubus fruticosus* | Rosaceae | + | + | + | + |
| *Salvia officinalis* | Lamiaceae | | | | + |
| *Satureja thymbra* | Lamiaceae | + | | + | + |
| *Smilax aspera* | Smilacaceae | + | | + | + |
| *Spartium junceum* | Fabaceae | | + | + | + |
| *Ulmus campestris* | Ulmaceae | + | | | + |
| *Vitex agnus-castus* | Lamiaceae | + | + | + | |

Appendix III. **Presence (+) of the breeding bird species in the olive groves under different management system and maquis.**

| **Bird species Scientific name** | **Bird species Common name** | **Family** | **Organic olive groves** | **Conventional olive groves** | **Abandoned olive groves** | **Maquis** | **Trophic status[1]** | **2009/147 Annexes** | **SPEC Category[2]** |
|---|---|---|---|---|---|---|---|---|---|
| *Caprimulgus europaeus* | Nightjar | Caprimulgidae | + | | + | + | I | I | 2 |
| *Carduelis cannabina* | Linnet | Fringillidae | + | | + | + | G | | 2 |
| *Carduelis carduelis* | Goldfinch | Fringillidae | + | + | + | + | G | | |
| *Carduelis chloris* | Greenfinch | Fringillidae | + | + | + | + | G | | |
| *Cettia cetti* | Cetti´s warbler | Sylviidae | + | + | | + | I | I | |
| *Cisticola juncidis* | Zitting Cisticola | Cisticolidae | + | | | + | I | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Cuculus canorus* | Common Cuckoo | Cuculidae | + | + | + | + | I | I | |
| *Emberiza cirlus* | Cirl Bunting | Emberizidae | + | + | + | + | I/G | | |
| *Emberiza melanocephala* | Blackheaded Bunting | Emberizidae | + | + | + | + | I/G | | 2 |
| *Erithacus rubecula* | European Robin | Muscicapidae | | | | + | I | | |
| *Fringilla coelebs* | Common Chaffinch | Fringillidae | + | + | + | + | G | | |
| *Galerida cristata* | Crested Lark | Alaudidae | + | | | | I/G | | 3 |
| *Garrulus* | Eurasian Jay | Corvidae | + | + | + | | O | | |
| *Hippolais olivetorum* | Olivetree Warbler | Acrocephalidae | + | + | + | + | I | I | |
| *Hippolais pallida* | Eastern Olivaceous | Acrocephali | + | + | + | + | I | | 3 |
| *Lanius collurio* | Redbacked Shrike | Laniidae | + | | + | + | I | I | 3 |
| *Lanius minor* | Lesser Grey Shrike | Laniidae | + | | + | + | I | I | 2 |
| *Lanius nubicus* | Masked Shrike | Laniidae | + | | + | + | I | | 2 |
| *Lanius senator* | Woodchat Shrike | Laniidae | + | + | + | + | I | | 2 |
| *Luscinia megarhynchos* | Common Nightingale | Muscicapidae | + | + | + | + | O | | |
| *Miliaria calandra* | Corn Bunting | Emberizidae | + | | + | + | O | | 2 |
| *Muscicapa striata* | Spotted Flycatcher | Muscicapida | + | | + | + | I | | 3 |
| *Oenanthe* | Blackeared | Muscicapida | | + | | + | O | | 2 |
| *Oenanthe leucura* | Black Wheatear | Muscicapidae | + | | | + | O | I | 3 |
| *Parus caeruleus* | Blue Tit | Paridae | | | + | + | I | | |
| *Parus lugubris* | Sombre Tit | Paridae | + | + | + | + | I/G | | |
| *Parus major* | Great Tit | Paridae | + | + | + | + | I | | |
| *Passer domesticus* | House Sparrow | Paridae | + | + | | + | I/G | | |
| *Streptopelia turtur* | European Turtle Dove | Columbidae | + | + | + | + | G | I I/2 | 3 |
| *Sylvia atricapilla* | Eurasian Blackcap | Sylviidae | | | | + | O | | |
| *Sylvia cantillans* | Subalpine Warbler | Sylviidae | + | | + | + | I/F | | |
| *Sylvia hortensis* | Orphean Warbler | Sylviidae | + | + | + | + | I | | 3 |
| *Sylvia curruca* | Lesser Whitethroat | Sylviidae | | | + | | I | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Sylvia* | Sardinian Warbler | Sylviidae | + | + | + | + | I | | |
| *Turdus merula* | Common Blackbird | Turdidae | + | + | + | + | O | II/2 | |
| *Upupa epops* | Eurasian Hoopoe | Upupidae | + | + | + | + | O | | 3 |

[1] I:insectivorous; G:granivorous; I/G: insectivorous/granivorous; O:omnivorous; I /F: insectivorous/frugivorous. [2]'SPEC 1' Species of global conservation concern, i.e., classified as globally threatened. Near threatened or data deficient; 'SPEC 2' for species with unfavorable conservation status in Europe whose global populations are concentrated in Europe; 'SPEC 3' for species with unfavorable conservation status in Europe whose global populations are not concentrated in Europe; 'SPEC 4' for species with a favorable conservation status in Europe whose global populations are concentrated in Europe.