Original Research

Alpha-Diversity of Differently Managed Agro-Ecosystems Assessed at a Habitat Scale

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Abstract

As agriculture continues to be a major contributor to water pollution, climate change and loss of biodiversity in the EU, agro-environmental measures have been introduced to encourage conventional farmers to acquire more sustainable organic practices. This study analyzed the effect of different intensity farm management (conventional and organic) on variations of floristic diversity in crop fields (C) and non-production areas – uncropped field margins (UCM). The outcomes of the study can thus support the creation of a more diversified set of habitats and greater landscape heterogeneity. The main goal of this research was to evaluate and compare the impact of organic and conventional farming on plant diversity at a habitat scale (alpha-diversity). Assessments were carried out on differently anthropogenized agro-environment background (C and UCM) of organic and conventional agriculture at the Lithuanian University of Agriculture. It was observed that sustainable land use (OF) leads to preservation of biodiversity, which is the element of crucial importance for landscaping. Registered total plant diversity was represented by 127 species ranked in 21 plant families of *Magnoliophyta* (*Angiopsermae*) and 1 family of *Equisetophyta,* depending on farming type and habitat anthropogenic level. The field margins habitat of organic farming provide the maximal species diversity (71 sp.; 3.6 alpha-diversity index). Conventional farming management emerged as the negative impact on floristic diversity (2.1-2.9 alpha-diversity index) due to the intensive application of chemical fertilizers and various pesticides during plant vegetation.

Keywords: alpha-diversity, diversity index, agro-environment

Introduction

Agricultural development in Central Europe over the past 5,000 years has resulted in anthropogenic transformation, namely the translation of old-growth woodland into mosaic landscape with agricultural and semi-natural habitat [1-3]. Moreover, occurred landscape changes, caused by human-driven land-use, and climatic changes are attributed with a continual increase in the scope and complexity of ecological problems, growing destabilization of natural household and ascending irreversible changes [4, 5].

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In the middle of the 20th century traditional and diverse management of farming was replaced by modern, highly specialized conventional agriculture. Indeed, intensification of agriculture was achieved by application of high cropping technologies that employed high-yielding cultivars, mineral fertilizers, pesticides, and irrigation in dried regions. These enumerated agricultural measures determined tremendous increases in food production [6]. On the other side, large territories with unfavorable climate, topography, and poor soils were threatened by abandonment. In consequence, the small-scale mosaic of grassland and arable fields which have created and upheld high diversity of habitats diminished and was replaced with extensively managed grasslands or forests [7]. Enlargement of arable fields and

Table 1. Agro-environment scheme management options included in this study.

Site/habitat	Management options			No. of relevés	Rotational
	OF EF	CF TF	CF RS		
UCM	Regularly cut margin, no chemical fertilizer and pesticides (5 relevés)	Spring fallow, herbicides (5 relevés)	Regularly cut margin, chemical fertilizer and pesticides (5 relevés)	15 (5x3)	No
C	Regularly cultivated field, only certificated (organical) fertilizers (5 relevés)	Regularly cultivated field, chemical fertilizers and pesticides (5 relevés)	Regularly cultivated field, chemical fertilizers and pesticides (5 relevés)	15 (5x3)	Yes
No. of relevés	10 (5x2)	10 (5x2)	10 (5x2)	30	

farming intensification are considered as the main causes which lead to a decrease of plant species diversity in agro-environment [8]. As many authors report, floristic cover declined in diversity over the last few decades in arable fields, grasslands and boundary sites [9, 10]. Therefore, farming intensification together with other anthropogenic factors had the fundamental impact on loss of biodiversity during the last 1,000 years [11-14]. This particularly concerns the loss of vascular plant species as well as diversity of bio-cenosis and ecosystems in total [15].

Studies have indicated that farming management type (conventional or organic) affects both abiotic (soil, water, air) and biotic (species, communities, and biodiversity) resources [16-19]. Therefore, more diverse and sustainable management at a field level and increasing complexity of agricultural landscapes, which support higher biodiversity and result in enhanced ecosystem functions for pollination, pest control, or water quality, are supported in the EU and other countries [20, 21]. Interpretation of multiple results confirmed the possibility that organic farms may be predisposed to support higher biological diversity if they have greater habitat heterogeneity and already favorable management compared to other farms [22].

With respect to actuality of the conservation of biodiversity, the assessment and evaluation of alpha-diversity became actual in agricultural areas. As EC Regulations (EEC, No. 2078/92) refer, the deeper knowledge of the positive and negative impacts of agriculture on biodiversity is required. Therefore, the main objective of this study was to investigate biodiversity response to different farming systems (conventional and organic) and to habitat (crop field and their margin) anthropogenic levels by inventorying the biodiversity of plant species.

Materials and Methods

Study Site

The biodiversity inventory was conducted at the Ecological Farm (EF), Training Farm (TF), and in Research Station (RS) of the Lithuanian University of Agriculture (LUA; 54º52′58″N, 23º50′21″E), Kaunas district, during 2006-09. The site is located in hardiness zone 5-6 [23] of temperate climate C, with moderately warm summer and moderately cold winter [24]. Annual average temperature ranges between 5.5-7.5ºC, with annual precipitation of 670 mm. Total solar radiation inflow amounts to 3,600 MJ m^{-2} in Lithuania. On total area of ca 200 ha, six distinct habitats were delineated. First of all, there were two investigated habitats of different anthropogenic levels defined: crop fields (C) and uncropped cultivated margins (UCM). Furthermore, two different farming systems were excluded: organic farming (OF) and conventional farming (CF). More specifically, the OF was investigated at the Ecological Farm, whereas the CF was investigated at the Training Farm (TF) as well as the Research Station (RS) (Table 1). All investigated sites are mapped as a single soil type: sandy moraine loam humic horizon of *Calcari-Epihypogleyic Luvisol*, LVg-p-w-cc [25]. The soil pH varied from 7.1 to 7.0 and humus content was medium (2.3-2.5%).

Sampling Design and Statistical Analysis

Alpha-diversity, which is usually measured and expressed within habitat-patch-scale, was investigated at differently anthropogenized habitats. The initial data of phyto-diversity was obtained in crop fields, as well as uncropped cultivated margins of Ecologic Farm and in conventional farming (CF), namely at the Training Farm (TF), and at the Research Station (RS) in summer (June-July). Species biodiversity was registered by the most widely used method of habitat general vs. species list at alpha-diversity scale [26, 27]. The relevés plot size of 1.0 m^2 was selected due to relatively low biodiversity. Relevés in 5 replications were set out along transects in sections of 20-25 m in each study site of different anthropogenic and management types [28]. The sample therefore encompassed 30 plots/relevés in total recorded in six anthropogenized habitats of differently managed (conventional CF and organic OF) crop fields and their uncropped margins (Table 1).

The registered plant species were listed by following the commonly used taxonomical and nomenclature interpretation [29, 30]. The species cover (p) and abundance (A) were recorded in accordance with Braun-Blanquet classification scale [31].

Plant diversity was registered at habitat scale (alpha-diversity) accordingly to the Shannon-Wiener method [32]. More specifically, the Shannon-Wiener biodiversity index

H' ($H'=-\sum p_i \ ln \ p_i$) of non cultivated species richness or alpha-diversity with relative abundance, expressed as a proportion of total cover (p_i), was used [28].

Additionally, the standard deviation (SD) of the presentation of each species was recorded in investigated sites at statistical significance $p<0.05$.

Management of Farm Habitats

Mineral ($N_{120}P_{90}K_{90}$, $N_{90}P_{60}K_{60}$) and 60 t·ha^{-1} of manure annual fertilizing was used in conventional (TF and RS) and organic farming (EF) systems, respectively. In addition, pesticides were applied (1-1.56 times per yr) only in crops of conventional farming. Vegetation cover of CF UCM was managed by spraying herbicides and therefore provided a more open crop canopy with greater benefits for arable plants.

Only certified, environmentally sustainable agro technical measures were applied in OF, instead of chemical fertilizers and pesticides applied in CF RS and TF. UCM is narrow (1-2 m wide) linear shaped semi-natural landscape element situated along of OF and CF crop fields [33]. Anthropogenized semi-natural grassland of RS and OF UCM was cut regularly.

Results and Discussion

Agreeably to Piorr et al. [34], current land use techniques are responsible for a loss of biodiversity in contradiction with fact, that the increasing land use 1000 yrs ago fostered the development of a high level biodiversity of species in Central Europe. The maximal average phyto diversity (81 sp.) at habitat scale was observed under sustainable farming conditions at the Ecological Farm during 2006-09 (Fig. 1). These biodiversity findings from different land use coincide with data from other studies [35]. A conventional farming system is the most aggressive with respect to habitat environment due to the application of various pesticides (herbicides, insecticides, fungicides, etc.) and "effective" doses of chemical fertilizers ($N_{120}P_{90}K_{90}$). The lowest biodiversity (24 sp.) was therefore observed in the Training Farm of Lithuanian University of Agriculture. Furthermore, more favorable conditions at the Research Station resulted in an increase of biodiversity (56 sp.) in comparison with the Training Farm. Despite these facilities being under a CF regime, the RS is oriented toward scientific activities, whereas the TF is production-oriented and hence more intensive farming technologies are employed there. These data affirmed the interaction between farming type (different cultivation, chemical fertilizers, and pesticides) and habitat biodiversity variation, which is mentioned by some authors [35, 36]. The human activity has changed biodiversity in the Ecologic Farm, where 12 perennial species, mostly hydrophytes, disappeared due to the dismantling of hydro towers and land reclamation in 2006. These actions stipulated the changes of habitat eco-conditions and floristic diversity during 2006-07. On the other hand, the same number of new species (12 sp.) established and total number of species persist (70 sp.) in 2007, with 81 species in total being registered in OF during 2006-07. Nonetheless, harmful invasive (EPPO 2000/29/EC) or Red List [13] species were not registered in investigated territory.

Registered plant diversity was represented by 21 plant families of *Magnoliophyta* (*Angiopsermae*) and 1 family of *Equisetophyta* depending on the farming system and habitat (Table 2). *Magnoliopsida* predominated over *Liliopsida*. *Liliopsida* (*Monocotyledonae*) was peculiar with the lowest level of diversity, since only three families representing this class were recorded. However, the *Poaceae* family of this class was represented by the largest number of genus (4-13) and species (7-16). The following sequence represents the abundance of *Magnoliopsida* (*Dicotyledonae*) families in descending order: *Asteraceae*>*Fabaceae*> *Brassicaceae* >*Caryophyllaceae*>*Rosaceae*>*Polygonaceae*>*Scrophulariacea*>*Onagraceae*>*Apiaceae*>*Lamiaceae*>*Geraniaceae* >*Plantaginaceae*. Remaining families, namely *Boraginaceae*, *Chenopodiaceae*, *Violaceae*, *Urticaceae*, *Rubiaceae*, and *Equisetaceae,* were monotypic. The absence of bryophyte species in vegetation cover of all research areas indicated sufficient soil fertilizing and optimal pH for plants.

Spatial analysis of vegetation proved a different response of plant biodiversity to anthropogenization levels (arable fields under winter crop and uncropped margins) and farm management systems (organic and conventional) (Fig. 2). The highest richness of plant species occurred in semi-natural habitats – UCM (with the exception of CF TF) – in comparison with higher anthropogenized agro-ecosys-

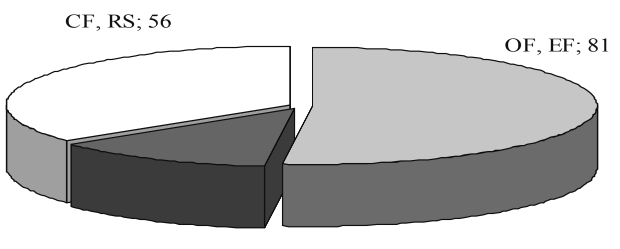

Fig. 1. Biodiversity responses to different land management types (mean±SD intervals, $p<0.05$).

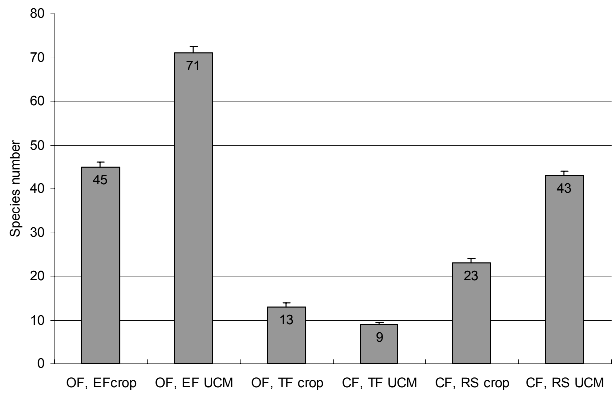

Fig. 2. Habitat biodiversity response to anthropogenic levels and farming types (mean±SD intervals, p<0.05).

Table 2. Taxonomic diversity presented in different intensity agro ecosystems.

Family	Genus			Species		
	EF	RS	TF	EF	RS	TF
1. *Poaceae (Liliopsida)*	13	10	4	16	12	7
2. *Asteraceae(Magnoliopsida)*	10	11	3	12	12	3
3. *Fabaceae (Magnoliopsida)*	5	3	-	9	3	-
4. *Brassicaceae (Magnoliopsida)*	5	5	-	6	5	-
5. *Caryophyllaceae (Magnoliopsida)*	3	3	1	4	3	1
6. *Rosaceae (Magnoliopsida)*	3	1	-	3	1	-
7. *Polygonaceae (Magnoliopsida)*	3	4	-	5	5	-
8. *Scrophulariaceae (Magnoliopsida)*	4	1	1	4	2	1
9. *Onagraceae (Magnoliopsida)*	2	1	-	2	1	-
10. *Apiaceae (Magnoliopsida)*	2	1	-	2	1	-
11. *Ranunculaceae (Magnoliopsida)*	1	1	-	3	1	-
12. *Lamiaceae(Magnoliopsida)*	1	-	-	3	-	-
13. *Geraniaceae (Magnoliopsida)*	-	-	-	2	-	-
14. *Juncaceae (Liliopsida)*	1	-	-	2	-	-
15. *Plantaginaceae(Magnoliopsida)*	1	1	-	1	2	-
16. *Cyperaceae (Liliopsida)*	1	1	-	1	2	-
Monotipic families and genus						
17. *Chenopodiaceae(Magnoliopsida)*	1	1	1	1	1	1
18. *Violaceae(Magnoliopsida)*	1	1	-	1	1	-
19. *Urticaceae(Magnoliopsida)*	1	-	-	1	1	-
20. *Rubiaceae(Magnoliopsida)*	1	1	-	1	1	-
21. *Equisetaceae (Equistophyta)*	1	1	-	1	1	-
22. *Boraginaceae (Magnoliopsida)*	-	1	-	1	1	-
Total: 22	61	48	10	81	56	20

tems – crops in all investigated farming systems. Lower plant diversity was observed in cropped fields, possibly due to pressing competition from the high-density crops. The same results were obtained by other authors [37, 38].

Results of investigation suggested that at its early stage, organic farming cannot suppress weed populations to the same level as previously applied measures of conventional cropping [39]. Their stand cover was not complete, and therefore crops were unable to compete with weeds. Thus, organic farming offers some benefits for biodiversity. The largest diversity (71 sp.) was obtained in UCM and in crop fields (45 sp.) habitats of OF LUA. OF UCM was the most diverse option with the greatest number of grasses and forbs species, also with that of ruderal and segetal perennials and annuals. Perennial grasses and forbs predominated in plant cover of OF UCM (Fig. 3). The cover of some common grasses (*Poa pratensis* L., *Lolium perenne* L., *Festuca pratensis* L.) and forbs (*Taraxacum officinale* L.) species composed the significant share (25-40%) in plant cover of this habitat.

Data analysis suggested that diversity trends in CF RS UCM and crop (Fig. 4) followed that in OF analogical habitat. The intermediate number of species (56 sp.) confirmed lower intensity of conventional farming in the Research Station than that in Training Farm (20 sp.) (Fig. 2). There were 43 species established in UCM habitat of CF RS, if compared to all habitats of CF. This number of species is about twice bigger as that of species found in CF RS crop fields (21 sp.). Lower numbers of non-crop species occurred due to the application of mineral fertilizers and chemical control in CF crop fields.

With agreement to Crichley et al. [40], the vegetation removal followed by annual soil disturbance in field margins of conventional agriculture occurred as the main reason for the decrease of species diversity in the habitats of the Training Farm and Research Station. Agricultural disturbance stimulated the formation of empty gaps, therefore vegetation cover became incomplete and reduced in CF UCM. Therefore, soil cover with non-crop species ranged mostly between 1-2% in CF UCM habitat (Fig. 3). Misplaced fertilizers, nutrient and pesticide runoff can also seriously diminish habitat quality [41] by reducing species diversity both in TF crop fields (9 species) and UCM (13 species).

The obtained data confirmed that the total plant cover of non-cropped species varied depending on farming systems and anthropogenic levels of habitat. The cover of non-crop species was complete and the highest on EF UCM, where-

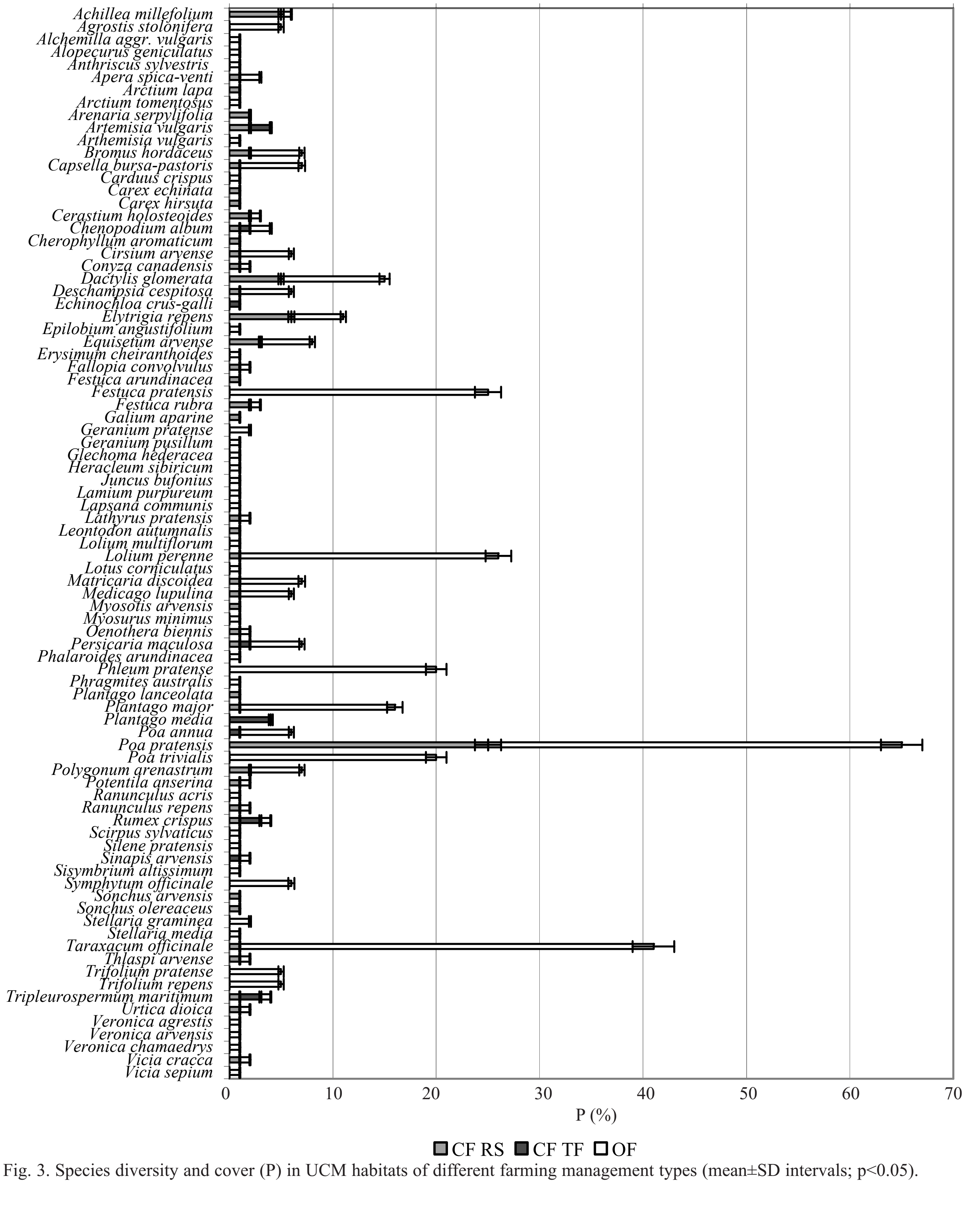

Fig. 3. Species diversity and cover (P) in UCM habitats of different farming management types (mean±SD intervals; p<0.05).

as the least (only 15%) was on TF UCM. The plant cover formed in OF UCM was more closed and even in comparison with CF UCM.

Statistically significant ($p<0.05$) differences in Shannon diversity index H' was observed throughout tested habitats (Fig. 5). Positive diversity response to sustainable organic farming was reported previously [42] and was confirmed in this study. The lower land use intensity in OF caused the highest biodiversity in OF UCM and crop habitats with mean alpha-diversity values 3.6 and 3.2 respectively. Species richness negatively responded to conventional land management [39, 43, 44], therefore diversity index H' declined in CF RS and ranged between 2.9-2.6. The regular mown road verges (CF TF UCM habitat) and the most intensive soil cultivation, and widespread use of chemical fertilizers and pesticides (CF TF C habitat) resulted in CF habitats losses of biodiversity. The lowest species diversity was hence determined in CF TF UCM (H'=2.1) and C (H'=2.5) habitats. Obviously, land-use types and changes could be projected to cause broad-scale global land-cover transformations that will increase species extinction rates. Maintaining suitable habitat conditions in field margins (e.g. OF UCM) will foster species richness and conservation in agricultural background. Moreover, undisturbed and complete vegetation of UCM cover composed of perennial species could serve as a natural barrier for interference of alien species.

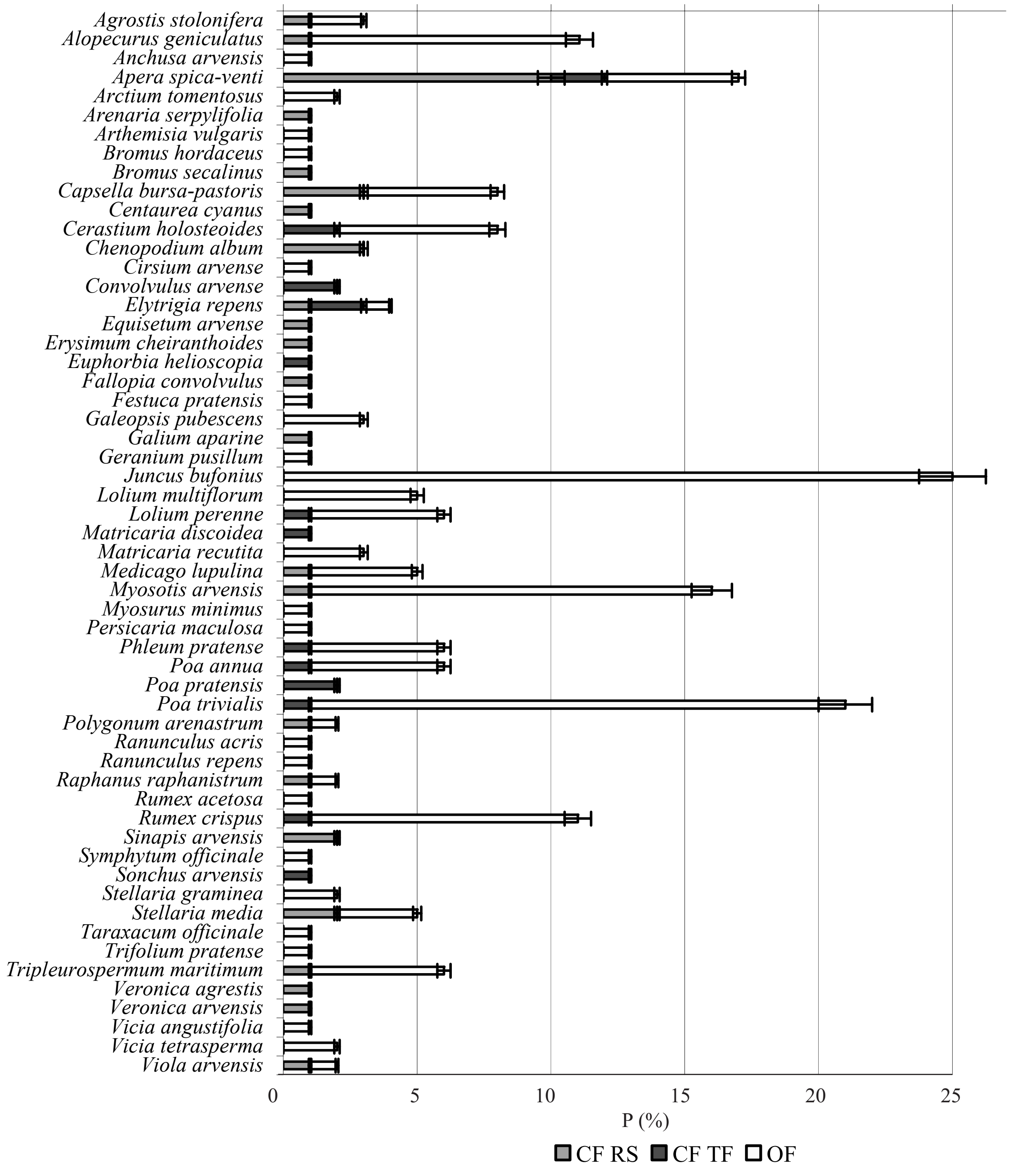

Fig. 4. Species diversity and cover (P) in crop habitats of different farming management types (mean±SD intervals; p<0.05).

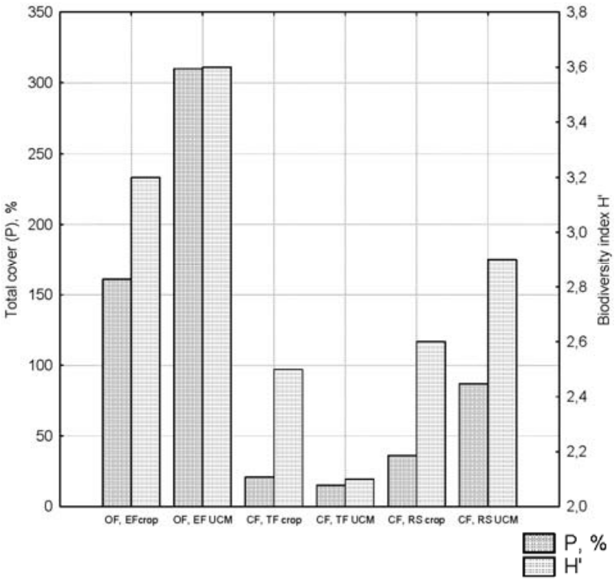

Fig. 5. Farming impact on alpha-diversity index and total cover of non-crop species.

Conclusions

Registered plant taxonomic diversity was represented by 127 species, which belong to 21 families of *Magnoliophyta* (*Angiopsermae*) and 1 family of *Equisetophyta* and were dispersed depending on farming system and habitat type. Sustainable, environment-friendly managed organic farming caused the highest alpha-diversity possibly due to the absence of mineral fertilizers and various pesticide applications. Additionally, manure application could have possiblly conducted the biodiversity increase in fields of organic farming. An extensive organic land management therefore has great importance in preserving floristic diversity due to the maintenance of sustainable environmental conditions in agro habitats.

Anthropogenic levels of habitat had great effect on species diversity and composition. Therefore, less anthropogenized uncropped field margins of both conventional and organic farming systems (with the exception of CF, TF, UCM) support significantly higher diversity (alpha-diversity ranged between 2.9-3.6) than that observed in conventionally managed cereal crop fields (alpha-diversity ranged between 2.5-3.2 only). Thus, semi-natural habitats of UCM presumably are colonization sources of ruderal and perennial forbs species that may spread into arable field. Permanent vegetation (grasses and perennials) tended to be associated with less cultivated and uncropped margins of the Ecological Farm. Segetal annuals of synanthropic vegetation predominated in cereal crop habitats (both CF and OF). Different agricultural measures and disturbances might also be a possible explanation for the variation between cultivated (crops) and uncropped (margins) areas. The local conservation of uncropped margins must be prioritized in order to find ecological solutions to the biodiversity crisis in a sustainable agricultural landscape.

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