



How can an intensively used agricultural landscape preserve diversity of Orthoptera assemblages?

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Abstract

Protecting biodiversity of agricultural lowlands is one of the main topics of European nature conservation. Understanding the relationship and interaction between cultivated and other habitat types is necessary since arable lands cover a significant part of the landscape, but former studies rather focus on the remaining semi-natural sites. Orthoptera assemblages, which are sensitive indicators of habitat structure and conservation value, were studied in a traditional intensively used agricultural area (it has been cultivated for several decades or even 250 years) to assess how arable land and ruderal linear habitats together can preserve insect diversity. Twenty-nine Orthoptera species, including protected *Gampsocleis glabra*, *Acrida ungarica* and *Celes variabilis* were recorded. We identified four assemblages and their character species reflecting intensity of land use. Assemblages of agricultural sites differed from the assemblages of semi-natural habitats used as control group. Revealing their quantitative composition, ratios of lifeforms and ecotypes, character species, and use of Grasshopper Conservation Indexes (GCI) helped to identify habitat types that can effectively preserve natural insect diversity, even under long-term intensive land use regime.

Implications for conservation Considering our findings, the role of linear ruderal habitats and less intensively cultivated arable lands covered by alfalfa and red clover in maintaining of biodiversity is higher than it was formerly assumed. Increasing ratio of these less intensive cultures (at least to 5%, optimally 8–10%) and its connection with each other and linear ruderal habitats may provide temporary habitats and corridors for metapopulations living in mosaic landscape. The local greening programs can help Orthoptera conservation as well through supporting the production of these cultures. Complex landscape- and crop rotation planning, that regard the spatial and temporal distribution, and ratio of agriculture landscape elements may become an effective tool for biodiversity conservation and forming sustainable farming systems.

Keywords Diversity · Species composition · Land use · Cropland · Vegetation structure · Secondary habitats

Introduction

The majority of the European grasslands have been transformed into secondary semi-natural and agricultural habitats due to long-term agricultural land use, thus one of the most important tasks of nature conservation is to protect the remaining biodiversity of these transformed agricultural

landscapes (Sutherland 2004; Batáry et al. 2015). Maintaining and protecting these ecosystems is important not only for nature conservation, but for agriculture as well, because of the outstanding role of ecosystem-services it provides (Boetzl et al. 2021).

The percentage of agricultural lands is 57% in Hungary, containing 15% grasslands and 81% croplands (KSH 2021). In order to achieve efficient protection and sustainable use of these ecosystems, the natural and even conservation value of their elements and the way they function should be known.

Orthopterans are especially sensitive and widely used indicators of grassland structure and naturalness (Marshall 2010; Benton 2012; Cherrill 2015). In the temperate zone, their assemblages are relatively species-rich and play an important role in the food chain especially as herbivores (Gardiner et al. 2005). Composition of Orthoptera

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assemblages refer especially to the vegetation structure of their habitats. Since the species composition, dominance rank structure and changes of life form spectra of their assemblages sensitively and quickly follow changes of their habitats and they can be used as indicators of grassland naturalness as well, they are widely used in grassland ecology and conservation planning (Noss 1990; Spellerberg 1991; Pearson 1994; Kisbenedek 1997; Báldi and Kisbenedek 1997; Batáry et al. 2007; Kenyeres 2011; Báldi et al. 2013; Torma et al. 2014; Kenyeres et al. 2020).

There are numerous studies on the Orthoptera fauna and assemblages living in natural and semi-natural habitat patches nested within agricultural fields. The role of these habitats in maintaining diversity is mostly known, and the effect of their vegetation structure, isolation and area and intensity and way of habitat use on diversity were also studied. Higher landscape diversity and lower intensity of habitat use can maintain larger species-richness. Ditch banks, burial mounds (kurgans) and grassy field margins preserve high species-richness and later can also buffer the negative effects of pesticide use (Gause 1930; Marshall et al. 2006; Torma et al. 2018; Löffler et al. 2019; Deák et al. 2020, 2021; Szanyi et al. 2021).

The natural and semi-natural habitat patches are spread in the agricultural matrix (e.g. 70% in Hungarian lowland; Berényi 2011) containing arable lands and different parts of crop production infrastructure (different kind of roads and channels etc.). In the most intensively used areas this matrix stands alone without remarkable patches of natural and semi-natural habitats. To understand of the role and relationship of the habitat types of this matrix is necessary for protection of both its own ecosystem and the diversity of nested natural habitat patches (Vandermeer and Perfecto 2007; Syiem et al. 2018). The Orthoptera assemblages of the cultivated fields are less known, despite their outstanding role in the functioning of the landscape's ecosystem (Forman and Gordon 1981; Donald and Evans 2006; Melliger et al. 2017). The study of assemblages living in arable lands can reveal the role of different cultures and cropping systems in the maintenance of insect diversity and also provide useful data for the conservation of remaining natural habitat patches.

The Orthoptera assemblages of traditionally intensively used agricultural landscapes were studied in the Carpathian Lowland (East Hungary) using semi-natural habitats (pastures and hayfields) as control areas to reveal how main cultivars and other elements of the "agricultural matrix" preserve the original fauna. During a 3-year study, assemblages of different landscape elements and their quantitative character species were described and the effect of land use intensity as well as the cropping system on the species-richness and composition of Orthoptera assemblages was also evaluated. We aimed to designate

habitat types, cultivars and cropping system that can preserve higher insect diversity and can be suggested for landscape engineers and farmers to forming a sustainable farming system.

Materials and methods

Study area

Studies were carried out in the northern part of the Carpathian Lowland, in the surroundings of Tiszaújváros, Sajószöged, Sajóörös and Kesznyéten in 2018–2020. The studied habitats have been used in the same way they are used nowadays for at least 80 years, but most arable lands have been regularly cultivated for 250 years based on military maps (<https://maps.arcanum.com/hu/>). In 2018, study sites were designated into three main habitat types: (1) semi-natural habitats: hayfields and pastures; (2) arable lands: red clover, alfalfa, sunflower, maize fields and stubble-fields; (3) linear ruderal habitats: country roadsides and channel banks, dirt roads and its grassy edges. In case of each habitat type 4–4 sampling sites (in total: 36 sites) were sampled each year of the three-year study. In 2019 and 2020 wheat field also appears in arable lands due to crop rotation (Table 1, Fig. 1).

Orthoptera sampling

Samplings were made by combined methods of sweep netting and direct search, which complement each other in Orthoptera studies and can provide comparable samples independently the vegetation structure (Nagy et al. 2007). Sweep net samples were taken by 200 sweeps with a net of 50 cm in diameter. The net was emptied after every 100 sweeps to protect sampled individuals. Sampling was done in calm and sunny weather considering the daily activity of the sampled species. The direct search was made by walking along parallel transects for 10 min at each sampling site and specimens were recorded based on both visual and acoustic detections along 1.5 m wide transects. Where the sweep net could not be used (e.g. in developed maize and sunflower cultures), a 30 min direct search was carried out. Samples were taken twice a year in each site and year in early June and late August. Data of the two samplings were summarized by sites.

Adults were separated from the samples and were identified at species level according to Harz (1957, 1960, 1975). The Orthoptera species file database was used (Cigliano et al. 2020) for nomenclature.

Table 1 Coordinates, type and mean intensity (Int.) value of habitat use of studied orthopterological sampling sites

No.	GPS: N	GPS: E	2018	2019	2020	Int
1	47°56'33"	21°1'59"	Maize	Maize	Stubble-Field	5.3
2	47°56'37"	21°1'51"	Sunflower	Wheat	Maize	5.7
3	47°56'41"	21°1'45"	Stubble-Field	Maize	Stubble-Field	4.7
4	47°56'48"	21°1'44"	Alfalfa	Wheat	Sunflower	4.7
5	47°56'47"	21°1'41"	Dirt Road	Dirt Road	Dirt Road	2
6	47°56'14"	21°0'22"	Dirt Road	Dirt Road	Dirt Road	2
7	47°56'23"	21°0'27"	Dirt Road	Dirt Road	Dirt Road	2
8	47°56'22"	21°0'29"	Stubble-Field	Maize	Maize	5.3
9	47°56'21"	21°0'28"	Sunflower	Wheat	Sunflower	5.7
10	47°56'47"	21°0'33"	Alfalfa	Alfalfa	Alfalfa	3
11	47°56'48"	21°0'36"	Sunflower	Wheat	Maize	5.7
12	47°56'47"	21°0'37"	Dirt Road	Dirt Road	Dirt Road	2
13	47°58'57"	21°3'2"	Pasture	Pasture	Pasture	1
14	47°59'19"	21°4'5"	Pasture	Pasture	Pasture	1
15	47°59'13"	21°4'2"	Hayfield	Hayfield	Hayfield	1
16	47°59'16"	21°4'31"	Hayfield	Hayfield	Wheat	2.3
17	47°59'2"	21°4'45"	Hayfield	Wheat	Wheat	3.7
18	47°59'34"	21°4'13"	Pasture	Pasture	Pasture	1
19	47°59'12"	21°3'32"	Pasture	Pasture	Pasture	1
20	47°57'5"	21°4'47"	Red Clover	Red Clover	Red Clover	3
21	47°57'54"	21°4'52"	Red Clover	Red Clover	Red Clover	3
22	47°57'51"	21°4'58"	Red Clover	Red Clover	Red Clover	3
23	47°57'51"	21°4'29"	Red Clover	Alfalfa	Red Clover	3
24	47°57'5"	21°4'22"	Alfalfa	Alfalfa	Alfalfa	3
25	47°55'55"	21°1'12"	Country Road Side	Country Road Side	Country Road Side	2
26	47°56'12"	21°1'0"	Sunflower	Sunflower	Maize	6
27	47°56'16"	21°1'0"	Maize	Maize	Wheat	5.7
28	47°56'8"	21°0'43"	Country Road Side	Country Road Side	Country Road Side	2
29	47°56'54"	21°0'35"	Country Road Side	Country Road Side	Country Road Side	2
30	47°57'27"	21°0'55"	Hayfield	Hayfield	Hayfield	1
31	47°57'27"	21°0'58"	Maize	Maize	Maize	6
32	47°56'49"	21°2'11"	Stubble-Field	Wheat	Maize	5
33	47°56'49"	21°1'59"	Stubble-Field	Maize	Maize	5.3
34	47°56'5"	21°2'1"	Country Road Side	Country Road Side	Country Road Side	2
35	47°56'42"	21°1'56"	Alfalfa	Alfalfa	Alfalfa	3
36	47°56'27"	21°0'31"	Maize	Maize	Sunflower	6

Data analysis

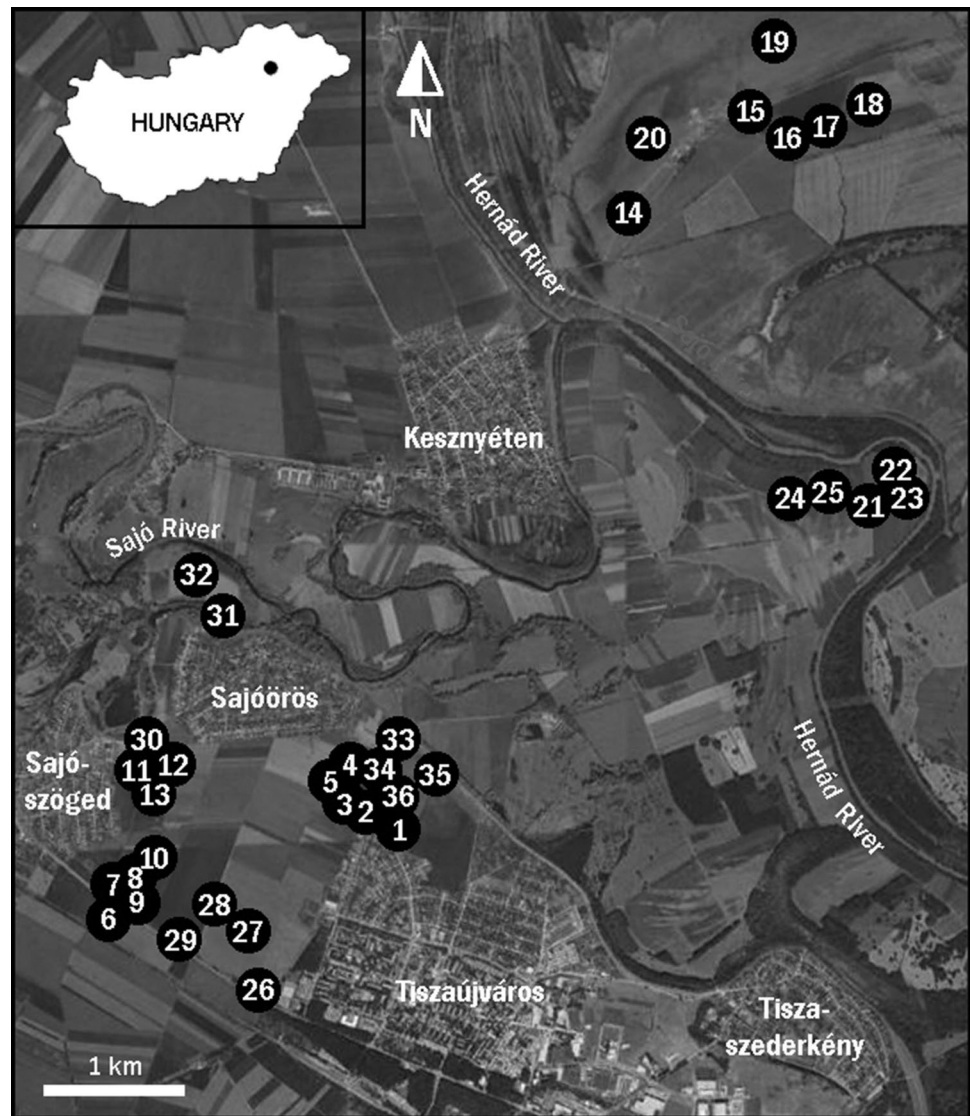
The Orthoptera fauna of the studied region was characterised by species-richness, relative frequency of species, life form and faunal types.

Principal Coordinate (PCoA) and cluster analysis with Bray–Curtis index were used to compare the sites based on the composition of Orthoptera assemblages. The Ward–Orlóci agglomeration method was applied for clustering (Podani 1997a). We used the relative frequency of species by sites for multivariate analyses in the SynTax 2000 software (Podani 1997b). Since orthopterans were not

recorded in site 13 during the study, the data of 35 sites were involved in the analysis.

The sampling sites were categorized a priori into three main land use types (semi-natural, arable land, linear ruderal habitats) that also means different land use intensity, vegetation structure, degradation and disturbance. The correspondence between these a priori categories and the groups formed based on the multivariate analyses was studied. Considering crop rotation and changes in habitat use, intensity of land use of a given site was characterised by the mean intensity of habitat use in the three consecutive years. The intensity value (1–6) of the studied culture

Fig. 1 Location of the orthopterological sampling sites (grey dots: agricultural sites, single numbers: semi-natural sites) studied between 2018 and 2020 in surroundings of Kesznyéten and Tiszaújváros in the northern part of the Carpathian lowland. Dotted area = arable lands (Source: Google Earth 2022)



and/or habitat types depends on the vegetation structure, disturbance, using of pesticides and intensity of cultivation: pastures and hayfields = 1, country roadsides and dirt roadsides = 2, alfalfa and red clover fields = 3, stubble-fields = 4, wheat fields = 5, sunflower and maize fields = 6 (Table 1).

Assemblage types established by the multivariate analyses were characterised and compared based on their total species-richness, mean number of species, mean number of individuals, and mean relative frequencies of life and ecotype forms. To characterise and compare assemblages, Whittaker's index (S/α ; S = number of species, α = mean number of species) was also calculated for both assemblage types and the whole sample (Whittaker 1960). Species were grouped into life and ecotype forms according to Ingrisch and Koehler (1998). The mean intensity of land use of the sites grouped in the same type was also calculated and compared.

To evaluate the conservation value of the habitat types, a modified grasshopper conservation index (GCI^{*}) was used based on Matenaar et al. (2015) and Szanyi et al. (2021). In the case of the original index, Matenaar et al. (2015) used three parameters: endemism, dispersal capacity and rarity, and each of them were grouped into three classes. The parameters were summed for each species and divided by nine (the maximum value) to obtain a GCI value between zero and one. Considering the distribution of the species living in the studied assemblages (there were no endemic species in the studied sites), a modified index was used, same as that of Szanyi et al. (2021). Instead of endemism, the rarity of the species in European regions were used based on distribution data of Heller et al. (1998): distributed in all 12 European regions (= 1), distributed in 9–11 regions (= 2), distributed in 6–8 regions (= 3), distributed in 1–5 regions (= 4). In the case of dispersal capacity and rarity, the original method was followed but the parameters

were grouped into four categories. Considering rarity, the categorization of Nagy and Rácz (2007) was followed. For dispersal capacity, the groups of well flying (= 1), poorly flying (= 2), wing-dimorphic (= 3) (also contains mesopterous mainly flightless species) and flightless (= 4) (contains wingless, macropterous and mesopterous flightless species) species were used. The local rarity was measured upon the spatial constancy (SC) of species in the studied 36 sites. A species was considered as common (= 1; $SC > 0.6$), frequent (= 2; $SC = 0.3–0.59$), low frequent (= 3; $SC = 0.1–0.29$) and rare (= 5; $SC < 0.1$). The three parameters were summed and divided by 12 (the maximum value) to obtain a GCI' value between zero and one. The GCI' values of the study sites were determined as a sum of the values of the species of the given site. Habitat types were characterised by the mean number of the GCI' values of sites. The modified standardized grasshopper conservation index (GCI_n) was also calculated for sites by dividing GCI' by the number of species on the given site. While the GCI value belongs both to species number and value of the species, the GCI_n is not influenced by species-richness (Matenaar et al. 2015).

Since our data did not fulfil the requirements of parametric tests, comparison of the assemblage types were made with Kruskal-Wallis nonparametric test and when it showed significant differences, pairwise comparisons were made with Mann-Whitey U test using Statistica 7 program package. The assumptions of the parametric tests were tested with Levene-test (homogeneity of variances) and Q-Q plots (normal distribution).

Correlation between intensity of land use and different parameters of assemblages (number of caught individuals, number of caught species and GCI') was analysed with Pearson correlation analysis.

Quantitative character species ("indicator" species) of the assemblages were identified using the IndVal method (Dufrene and Legendre 1997). The species were hierarchically classified according to their fidelity within the site groups. The IndVal (IV) value is highest (100) when the given species is present in all samples of the given group and is also exclusive for this group of samples. The program calculates the IV values of each species at each hierarchy level of the clustering. The indicator value is given by the maximum value. The significance of IV values was determined by randomisation (1000 iterations). Analysis was carried out with the IndVal program.

Results

During the investigation 29 Orthoptera species (11 Ensifera and 18 Caelifera) were caught. Most of the species belonged to the pratnicol life form (90.67%) while the ratio of geofilic species was remarkably lower (7.40%) (Tables 2 and 4).

The most common species are all widely distributed eurytypic species of the Carpathian lowlands. The potential agricultural pest *Calliptamus italicus* reached larger local abundance and density than at a regional scale (Arnóczkyné et al. 2020) and the regionally rare *Chorthippus dichrous* showed large local abundance and spatial constancy. *Gampsocleis glabra* and *Celes variabilis* are rare and protected, while *Acrida ungarica* is a protected member of the Hungarian fauna (Nagy and Rácz 2007b; Heller et al. 1998; Rácz 1998a) (Table 2).

The total number of caught Orthopterans was 2121, 21.5% of which were larvae. The total number of adults identified at species level was 1664. In the whole sample *C. italicus* (14.7%), *P. parallelus* (13.1%), *C. dorsatus* (12.7%), *G. brunneus* (11.6%), and *O. rufipes* (9.9%) were the five most abundant species. The relative frequency of *C. oschei* (7.0%) and *R. roeselii* (5.2%) also exceeded 5%.

During quantitative multivariate analysis of the Orthoptera assemblages, four site groups were identified along a gradient. The 1st PCoA axis represented a gradient from semi-natural (I) to intensively used arable lands (IV), while the 2nd PCoA axis represented a gradient between species-poor intensive arable lands (IV) and the group of moderately species-rich arable lands and roadsides (III) (Fig. 2.). The hierarchy of these groups is shown by the cluster analysis (Fig. 3.). Values of Whittaker's index support the result of multivariate analysis. It showed the homogenous character of semi-natural and less intensively used agricultural habitats and large heterogeneity of assemblages living on intensively used arable lands (Table 4).

The correspondence between the a priori and cluster groups was total in case of semi-natural sites (I). The a priori group of linear ruderal habitats (e.g. roadsides) split between the two transitional group of agricultural habitats (II and III). These transitional groups also contained 6 and 5 arable lands respectively, while the remaining 9 intensively used arable lands formed a heterogeneous group (IV) at the end of the gradient (Table 3 and Fig. 2).

The species-richness of assemblages decreased from group of semi-natural sites to intensive arable lands following the gradient shown on the 1st axis of PCoA. The mean species richness and abundance of Orthoptera assemblages showed the same trend, and the semi-natural sites were the most species-rich ones. The species-richness of semi-natural and diverse agricultural habitats was significantly higher than that of intensive arable land, while less diverse agricultural habitats had intermediate values (Table 4).

The frequency of different life forms showed a similar pattern in case of all life forms excluding geophilic species, that showed the highest relative frequency in intensive arable lands. The difference was significant only in comparison with diverse agricultural lands, where the value was also significantly lower than in semi-natural sites. Parallely the ratio

Table 2 Checklist of the Orthoptera fauna of the studied area with life and ecotype forms (Ingrisch & Koehler 1997), relative frequency, spatial constancy and grasshopper conservation index (GCI¹) of the species. arb: arbusticol, geo: geophilic, gra: graminicol, pra: pratinicol, mes: mesophilous; hyg: hygrophilous, m-: moderately, xer: xerophilous

	LF	EF	RF (%)	spat. con. (%)	GCI ¹
<i>Acrida ungarica</i> (Herbst, 1786)	gra	Xer	0.30	11.11	0.67
<i>Aiolopus thalassinus</i> (Fabricius, 1781)	geo	Hyg	1.26	16.67	0.50
<i>Bicolorana bicolor</i> (Philippi, 1830)	pra	Xer	0.60	13.89	0.67
<i>Calliptamus italicus</i> (Linnaeus, 1758)	pra	Xer	14.66	63.89	0.42
<i>Celes variabilis</i> (Pallas, 1771)	geo	Xer	0.06	2.78	0.75
<i>Chorthippus oschei</i> (Helvesen, 1986)	mes	Mes	6.97	33.33	0.50
<i>Chorthippus dichrous</i> (Eversmann, 1859)	pra	Mes	3.73	75.00	0.75
<i>Chorthippus dorsatus</i> (Zetterstedt, 1821)	pra	Mes	12.68	52.78	0.67
<i>Pseudochorthippus parallelus</i> (Zetterstedt, 1821)	mes	Mes	13.10	61.11	0.42
<i>Chrysochraon dispar</i> (Germar, 1834)	mes	m-hyg	0.12	2.78	0.75
<i>Conocephalus fuscus</i> (Fabricius, 1793)	pra	Hyg	2.46	41.67	0.58
<i>Doclostaurus brevicollis</i> (Eversmann, 1848)	geo	Xer	0.36	5.56	0.75
<i>Euchorthippus declivus</i> (Brisout de Barneville, 1848)	pra	Xer	4.51	50.00	0.75
<i>Gampsocleis glabra</i> (Herbst, 1786)	pra	Xer	0.66	22.22	0.67
<i>Chorthippus biguttulus</i> (Linnaeus, 1758)	pra	m-xer	1.08	27.78	0.58
<i>Chorthippus brunneus</i> (Thunberg, 1815)	pra	m-xer	11.60	72.22	0.42
<i>Gryllus campestris</i> (Linnaeus, 1758)	geo	mes	1.14	16.67	0.75
<i>Leptophyes albobittata</i> (Kollar, 1833)	pra	mes	0.60	11.11	0.83
<i>Melanogryllus desertus</i> (Pallas, 1771)	geo	Xer	0.18	8.33	0.83
<i>Oecanthus pellucens</i> (Scopoli, 1763)	par	Mes	0.36	16.67	0.83
<i>Omocestus haemorrhoidalis</i> (Charpentier, 1825)	pra	Xer	4.51	69.44	0.50
<i>Omocestus rufipes</i> (Zetterstedt, 1821)	pra	m-xer	9.86	66.67	0.42
<i>Mecostethus parapleurus</i> (Hagenbach, 1822)	pra	m-hyg	2.04	25.00	0.67
<i>Phaneroptera nana</i> (Fieber, 1853)	arb	Mes	0.06	2.78	0.67
<i>Platycleis affinis</i> (Fieber, 1853)	pra	m-xer	0.24	11.11	0.67
<i>Roeseliana roeseli</i> (Hagenbach, 1822)	pra	m-hyg	5.17	66.67	0.42
<i>Ruspolia nitidula</i> (Scopoli, 1786)	pra	Hyg	0.90	22.22	0.58
<i>Tetrix bipunctata</i> (Linnaeus, 1758)	pra	m-hyg	0.12	5.56	0.83
<i>Tettigonia viridissima</i> (Linnaeus, 1758)	mes	Mes	0.66	22.22	0.42

Fig. 2 Ordination of Orthoptera assemblages of the 35 sampled sites (Bray–Curtis distance, inf. content: 1st axis = 29.80%, 2nd axis = 14.87%). A priori habitat types: empty square = semi-natural sites; empty dots = linear ruderal habitats; black dots = arable lands

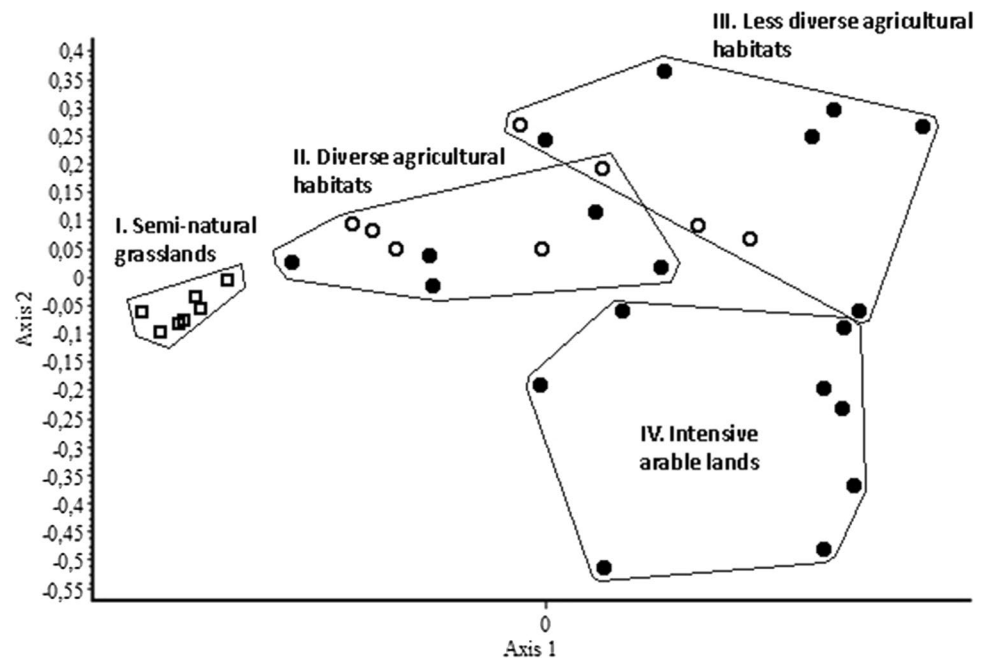


Fig. 3 Cluster analysis of Orthoptera assemblages of the 35 sampled sites (Bray–Curtis distance, MISSQ). A priori habitat types: empty square = semi-natural sites; empty dots = linear ruderal habitats; black dots = arable lands

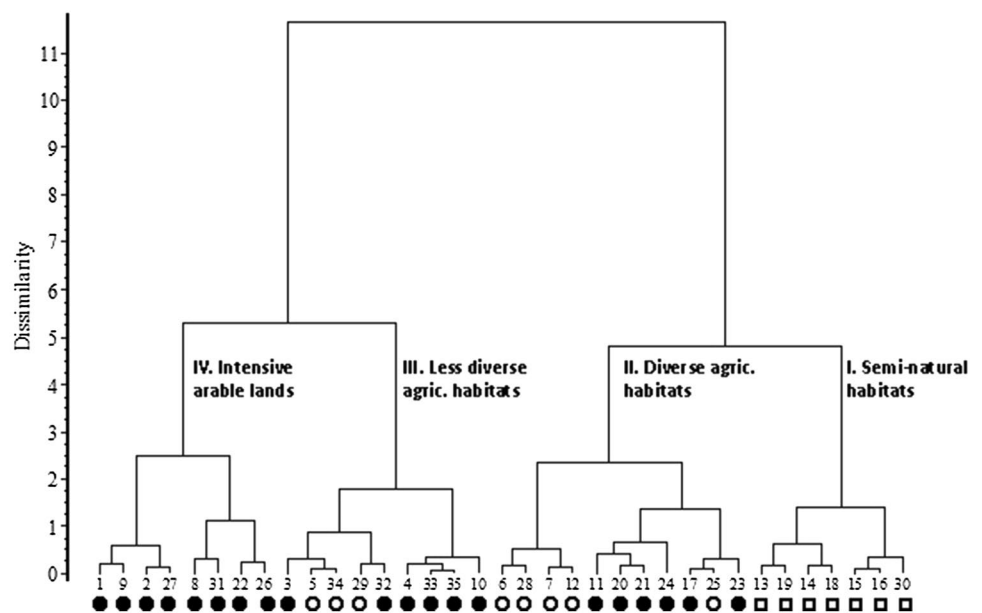


Table 3 Correspondence between the cluster groups and a priori categories of studied habitats

A priori habitat types	Total number of sites	I: semi-natural grasslands	II diverse agric. habitats	III. less diverse agric. habitats	IV. intensive arable lands
Semi-natural	7	7			
Other agricultural habitats	8		5	3	
Arable lands	20 (+ 1)*		6	5	9
Total number of sites	35 (+ 1)*	7	11	8	9

*Site without any Orthopterans sampled during the study

of pratnical species was lowest in intensive arable lands, but in this case, there were no significant differences. Regarding ecotypes the relative frequency of hygrophilous species continuously decrease from semi-natural habitats to more and more intensively used agricultural lands and between the intensively cultivated arable lands and semi natural sites it was significant difference. In the same time the ratios of moderately-xerophilous and xerophilous species were higher in more intensively used habitat types (Table 4).

The grasshopper conservation index (GCI') showed the highest conservation value of Orthoptera assemblages inhabiting semi-natural sites and the value decreased along the gradient shown by the 1st axis of PCoA. Conservation value of intensive arable lands was significantly lower than that of semi-natural and diverse agricultural lands, while the less diverse agricultural lands showed an intermediate value. The mean standardized GCI' showed the same trend, but in this case only the semi-natural sites had significantly larger conservation value than intensive arable lands and the other two types showed intermediate values (Table 4).

The mean value of land use intensity showed significant negative correlation with the number of caught specimens

($r = -0.7429$ $p < 0.0001$), species richness ($r = -0.767$, $p < 0.0001$) and the value of the grasshopper conservation index (GCI'; $r = -0.7702$, $p < 0.0001$) of the studied sites.

According to the results of the IndVal analysis, the most common species of the studied assemblages were *Chorthippus brunneus*, *C. biguttulus* and *Omocestus haemorrhoidalis*. The semi-natural and diverse agricultural habitats had ten mutual characteristic species (*Pseudochorthippus parallelus*, *Chorthippus dorsatus*, *Omocestus rufipes*, *Roeseliana roeselii*, *Euchorthippus declivus*, *Conocephalus fuscus*, *Chorthippus dichrous*, *Mecostethus parapleurus*, *Ruspolia nitidula* and *Bicolorana bicolor*), while the semi-natural sites alone were characterised by high fidelity and specificity of *Chorthippus oschei*, *Gampsocleis glabra*, *Aiolopus thalassinus* and *Dociostaurus brevicollis*. The diverse agricultural sites had no own character species. Contrarily, the less diverse agricultural habitats and intensive arable lands had only one mutual character species (*Gryllus campestris*). The less diverse agricultural sites could be characterised by *Calliptamus italicus*, and intensive arable lands had no own character species (Table 5.).

Table 4 Main characteristics of assemblage types (I–IV.) formed by multivariate analysis. Small letters refer to significant differences between the assemblage types based on Mann–Whitney U test ($p < 0.01$)

	I: semi-natural grasslands	II diverse agric. habitats	III. less diverse agric. habitats	IV. intensive arable lands	Total
Mean number of individuals (\pm SE)	79.71 \pm 18.00a	54.09 \pm 10.45a	45.89 \pm 5.56ab	12.25 \pm 3.32b	47.54 \pm 6.43
Total number of species (S)	26	24	20	16	29
Mean number of species ($\alpha \pm$ SE)	11.86 \pm 1.37a	11.64 \pm 0.78a	8.67 \pm 1.20ab	4.25 \pm 0.80b	9.23 \pm 0.71
Whittaker's index	2.19	2.06	2.03	3.76	3.14
Mean value of intensity (\pm SE)	1.19 \pm 0.19a	2.85 \pm 0.33ab	3.52 \pm 0.47b	5.33 \pm 0.35b	3.26 \pm 0.29
GCI'	7.11 \pm 0.87a	6.42 \pm 0.48a	4.74 \pm 0.71ab	2.22 \pm 0.43b	5.16 \pm 0.43
GCI _n '	0.59 \pm 0.01a	0.55 \pm 0.01ab	0.54 \pm 0.02ab	0.53 \pm 0.04b	0.55 \pm 0.01
<i>Life forms (mean RF% \pm SE)</i>					
Arbusticol	0.70 \pm 0.46	2.12 \pm 1.34	0.52 \pm 0.36	3.13 \pm 3.13	1.66 \pm 0.82
Pratinicol	92.32 \pm 2.53	96.83 \pm 1.42	94.80 \pm 2.92	76.06 \pm 12.07	90.67 \pm 3.12
Graminicol	0.58 \pm 0.58 \pm	0.21 \pm 0.14	0.37 \pm 0.37	0.00 \pm 0.00	0.28 \pm 0.15
Geophilic	6.39 \pm 2.33a	0.83 \pm 0.83b	4.32 \pm 2.78ab	20.81 \pm 12.42a	7.40 \pm 3.11
<i>Ecotype forms (mean (mean RF% \pm SE)</i>					
hygrophilous	6.63 \pm 0.91a	5.36 \pm 1.69a	3.54 \pm 2.23a	1.52 \pm 1.14b	4.27 \pm 0.91
moderately-hygrophilous	7.97 \pm 2.09ab	12.83 \pm 3.59a	2.43 \pm 1.34b	9.93 \pm 4.44ab	8.52 \pm 1.69
mesophilous	59.54 \pm 4.87a	33.80 \pm 1.20b	15.10 \pm 3.32c	25.99 \pm 10.59bc	32.36 \pm 3.75
moderately-xerophilous	18.88 \pm 4.64	23.17 \pm 1.49	23.86 \pm 5.17	41.76 \pm 10.44	26.74 \pm 4.64
Xerophilous	6.98 \pm 1.72a	24.84 \pm 2.78b	55.07 \pm 6.33c	20.8 \pm 6.32ab	28.12 \pm 3.70

Discussion and conclusions

The Orthoptera assemblages of common semi-natural grasslands and agricultural habitats including fields of the most important crops (maize, sunflower, wheat, alfalfa, and red clover) and linear ruderal habitats of the Carpathian Lowland were described. The sampled 29 species represented significant part both the regional (43 species; Arnóczykyné and Nagy 2021) and Hungarian Orthoptera fauna (Nagy 2003). Samples taken in a less studied area provide data on three protected species of which *Gampsocleis glabra* and *Acrida ungarica* appeared also in agricultural sites and *Celes variabilis* inhabited only semi-natural hayfields. The potential pest *Calliptamus italicus* and widely distributed *Chorthippus dichrous* showed larger local, than regional abundances, that provides special character of the studied moderately species rich assemblages (9.2 species/site in average).

The most abundant and frequent species of the local fauna belonged to the grass living pratinicol life form represented 90.67% of the sampled material. The relative frequency value of geophilic species (7.4%) was similar with average value of assemblages lives in xeric open grassland of the wider surroundings (Rácz 1998b, 2001).

Using multivariate analysis, four types of assemblages characteristic to the studied habitat types were identified that corresponded rather with the fine scale differences in

intensity of habitat use than the a priori categories of the studied habitats formed based on their naturalness. Szanyi et al. (2021) also proved strong effect of the intensity of the land use on composition of Orthoptera assemblages in the North-Eastern part of the Carpathian Lowland (West Ukraine). The correspondence between the a priori and cluster groups was univoque only in the case of semi-natural sites, while the arable lands and linear ruderal habitats separated along the 1st PCoA axis based on their species-richness and intensity of land use. The studied agricultural habitats have own characteristic assemblages that evolved under decades of habitat use and differ from the assemblages of semi-natural habitats of the same region. The relationship between insect assemblages of linear ruderal habitats and semi-natural sites is well studied (Ahmed et al, 2021; New et al. 2021), however the assemblages of intensively cultivated arable lands formerly were not take in consideration.

Most of the diversity and natural composition of the local assemblages represented by the studied semi-natural sites were preserved by the species-rich linear ruderal habitats (e.g. roadsides) and less intensively cultivated alfalfa and red clover fields. Although naturalness of these habitats measured with GCI values was lower than that of semi-natural sites, however comparing with intensively used arable lands (maize and sunflower fields) they had significantly higher natural value. The role of linear ruderal habitats (roadsides,

Table 5 Result of IndVal analysis: number of individuals in a given group of sites / number of occupied sites in a given group IndVal: indicator value of species; **: significant character species; NS: not significant; Gr.: cluster groups

Gr	Species	IndVal	I: semi-nat. grasslands	II diverse agr. habitats	III. less diverse agr. habitats	IV. intensive arable lands	
I	<i>Chorthippus oschei</i>	65.49**	80/6	24/7	11/5	1/1	
	<i>Gamsocleis glabra</i>	51.62**	7/5	3/2	1/1	0/0	
	<i>Aiolopus thalassinus</i>	45.75**	16/4	0/0	4/1	1/1	
	<i>Dociostaurus brevicollis</i>	28.57**	6/2	0/0	0/0	0/0	
I-II	<i>Pseudochorthippus parallelus</i>	88.05**	163/7	41/10	13/4	1/1	
	<i>Chorthippus dorsatus</i>	82.61**	57/7	119/11	32/7	3/2	
	<i>Omocestus rufipes</i>	79.34**	77/7	62/10	21/5	4/2	
	<i>Roeseliana roeselii</i>	74.79**	34/6	39/10	8/5	5/3	
	<i>Euchorthippus declivus</i>	66.13**	13/6	56/7	6/5	0/0	
	<i>Conocephalus fuscus</i>	48.43**	6/2	30/8	4/4	1/1	
	<i>Chorthippus dichrous</i>	45.75**	41/4	16/5	3/2	2/1	
	<i>Mecostethus parapleurus</i>	36.23**	14/3	14/5	0/0	6/1	
	<i>Ruspolia nitidula</i>	33.44**	7/3	6/4	2/1	0/0	
	<i>Bicoloranabicolor</i>	27.78**	2/2	8/3	0/0	0/0	
	II	No species					
	I-IV	<i>Chorthippus brunneus</i>	74.29NS	6/1	74/11	78/8	35/6
<i>Omocestus haemorrhoidalis</i>		71.43NS	4/3	32/10	22/8	17/4	
<i>Chorthippus biguttulus</i>		28.57NS	4/2	6/2	6/4	2/2	
III	<i>Calliptamus italicus</i>	85.81**	0/0	49/10	189/9	6/4	
III-IV	<i>Gryllus campestris</i>	27.95**	0/0	1/1	6/2	12/3	
IV	No species						
	Number of sites		7	11	9	8	

ditch banks and other linear landscape elements) in preserving Orthoptera diversity is well studied (Berggren et al. 2001, 2002; Vadkerti and Szövényi 2005; Eriksson et al. 2013; Torma et al. 2018). Studies mostly focused on the wildlife of natural and semi-natural patches nested within intensively cultivated arable lands (Duelli and Obrist 2003; Rand et al. 2006; Braschler et al. 2009; Jauker et al. 2009; Marini et al. 2010; Badenhauer and Cordeau 2012; Bátorý et al. 2016; Hall et al. 2022; Martínez-Núñez et al. 2022; Thorn et al. 2022). The distribution of sites a priori categorized as linear ruderal habitats (country roadsides, dirt roads) between cluster groups showed that the naturalness and diversity of these habitats and their assemblages may be affected by various factors e.g. the quality of neighbouring habitats, isolation and location, as it was found also in former studies (Torma et al. 2018; Rebrina et al. 2022).

Conversely, the importance of the cultivated areas is less known. Only the effect of the less intensive Fabaceae fields involved in the green direct payment scheme (“greening”) – part of the common agricultural policy of the European Union –, (e.g. alfalfa and red clover) were studied. Sites of greening programs are often designated in areas with originally higher natural value, thus the evaluation of their effect is quite difficult and often subject to

debate (Kleijn and Sutherland 2003; Uthes and Matzdorf 2013; Batáry et al. 2015). Since our agricultural sites are not involved in greening programs and each showed average natural value at most, the positive effect revealed on Orthoptera assemblages was not biased by the above-mentioned effect.

The intensive land use in the sunflower, maize and wheat fields led to less diverse insect assemblages with lower species diversity and conservation value. Three-year monoculture of maize and/or sunflower resulted in especially low average species-richness (only 4.25 species/site) and in some cases total absence of orthopterans. Fumí et al. (2021) also blamed the change of land use for the decrease of Orthoptera diversity. The increasing intensity of land use causes decreasing diversity of lepidopterans as well (Habel et al. 2019), while Onga et al. (2022) draw the same consequence assessing results of 199 studies.

Beyond linear ruderal habitats, less intensively cultivated alfalfa and red-clover fields can also maintain relatively species-rich Orthoptera assemblages with high conservation value. The grass-like structure of stubble and wheat fields can also provide a suitable habitat, while the intensive and especially the monocultural sunflower and maize fields are not suitable for orthopterans.

The ratio and spatial pattern of the different landscape elements (considering the grown cultures as well) greatly affect the diversity, composition and naturalness of the Orthoptera assemblages. Since they are sensitive indicators, this effect may be assumed in the case of many other grass-living insect assemblages. This showed that the role of the agricultural landscape elements is higher than it was formerly assumed. Changes of the ratio and proper planning of the spatial distribution of these constant (roadsides etc.) and temporal (different cultures) landscape elements and considering them as a complex system can be an effective tool, as it was partly suggested by Sirami et al. (2019). The augmentation of the ratio of less intensive (3–4 year) cultures and maintenance of the linear ruderal habitats together may increase the abundance and diversity of orthopterans, since these cultures can serve as temporary habitats and corridors or stepping stones between remained natural and seminatural habitats. In this way an enough diverse agricultural landscape can maintain species rich Orthoptera assemblages, however it is unable to preserve stenotopic characteristic species of natural habitats, as it was formerly proven in case of birds as well (Syiem et al. 2018). Nevertheless, results prove that this strategy can be effective even in traditionally intensively used areas, such as the Hungarian Lowland where most of the species-richness and conservation value could be maintained over the last decades.

Author contributions DAJ and AN designed the experiment and analysed the data, all authors contributed to writing of the manuscript.

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Code availability During the analysis SynTax 2000, and IndVal 2.0 were used, no computer code was created.

Declarations

Competing interests The authors declare no competing interests.

Informed consent Informed consent was obtained from all individual participants included in the study.

Research involving human participants and/or animals This article does not contain any studies with human participants performed by any of the authors. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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