Ecological structure of plant, insect and bird biodiversity and approaches to increasing the rationality of organic farming management (the case of Ukraine)

Nataliia Miroshnyk[1,2,*], Tetiana Grabovska[3,4], Vitalij Lavrov[9], Tatiana Shupova[1], Mykola Grabovskyi[5], Yuri Ternovyi [6], Hynek Roubík[7], Nataliia Prysiazhniuk[8]

[1]Institute for Evolutionary Ecology, National Academy of Sciences of Ukraine, Ukraine
[2]Research Institute for Sustainability – Helmholtz Centre Potsdam (RIFS), Germany
[3] Bila Tserkva National Agrarian University, Department of General Ecology and Ecotrophology, Ukraine
[4]Department of Food System Sciences, Research Institute of Organic Agriculture FiBL, Frick, Switzerland
[5]Bila Tserkva National Agrarian University, Department of Technologies in Crop Production and Plant Protection, Ukraine
[6]Skvyra Research Station for Organic Production, National Academy of Sciences of Ukraine,
[7]Czech University of Life Sciences Prague, Czech Republic
[8]Bila Tserkva National Agrarian University, Department of Ichthyology and Zoology, Ukraine
[9]Municipal Higher Educational Institution "Vinnytsia Academy of Continuous Education", Department of Ecology, Natural and Mathematical Sciences, Ukraine

* Corresponding author e-mail: natalie.miroshnik@outlook.com

Received: 10 April 2025 / Accepted: 14 August 2025

Abstract. The reduction of pesticides through organic farming releases some agricultural pest species from human control. We propose that this results in higher pest populations and indirectly, via plant diversity, affects avian community structure in agricultural landscapes. Therefore, we collected data on vegetation diversity (trees, bushes, herbs), from organic agrolandscapes and analyzed how vegetation diversity impacted the diversity and structure of insects and birds. The aim of this research is: i) To investigate the ecological, taxonomic, and functional structure of biodiversity in organic agricultural landscapes and its impact on ecosystem services. ii) To propose mechanisms for managing bird population in organic agro-ecosystems, considering biotic and transabiotic links. We used botanical, forestry and ecological methods to assess biodiversity.

We found that plant diversity increases and species dominance decreases in ecotones approaching forest belts, insect diversity depends on the crop planted in fields, and bird diversity depends on landscape connectivity and structure. Fourteen families of insects occurred in the winter wheat field, 22 families in the buckwheat field, and 15 families in the soybean field. Among these, phytophages (40-69%) dominated, parasitic species ranged from 18 to 24%, and predators accounted for 7-26% of the total number of individuals collected. Twenty-eight bird species (6 food specialists) fed in the fields, dominated by species with broad diets. The list of species feeding in an area depended on the qualitative characteristics of the forest belt surrounding the area. We conclude that birds can serve as a practical pest control if combined with additional organic farming economic and environmental management strategies. To preserve biodiversity, it is important to take into account the structure of the forest shelterbelts, types of habitats due to the expansion of fields' margins (ecotones), plants that resistant to damage by phytophagous insects, as well as tree species that can attract birds as a food base. Results on existing environmental risks and ways to mitigate them in organic farming can be used for systemic analyses of biodiversity structure in agro-landscapes: fields, their margins, forest shelterbelts, etc.

Keywords: avifauna, agricultural landscapes, invasive alien plants, entomofauna, organic farming, phytodiversity.

1. Introduction

The conversion of natural and semi-natural habitats into agricultural land often results in significant biodiversity loss, primarily due to the extensive fragmentation and destruction of habitats (Johannesdottir et al., 2017; Pringle et al., 2019). The excessive application of agrochemicals over many years in agricultural landscapes has disrupted the evolutionary correspondence of ecotope to biota, which relies on ecosystem stability and development. This disruption leads to irreparable biodiversity losses, global ecosystem structure disruptions, desertification, and alterations in global carbon and nitrogen cycles.

Therefore, in the face of increasing land use intensity, it is imperative to develop new approaches to biodiversity conservation and management in agricultural landscapes (Frei et al., 2018; Shaffer & DeLong, 2019). In organic agriculture, where the focus lies on utilizing technologies that do not harm living organisms through the more efficient use of natural mechanisms, the method of biological pest control serves as an alternative to the intensive application of agrochemicals. These chemicals often result in significant and long-term pollution of ecosystems and the irreversible destruction of pollinators (Ondine et al., 2009; Smith et al., 2010; Bennewicz & Barczak, 2020).

The systemic analysis of new knowledge and lessons learned, conducted by Tribel et al. (2012), allowed for the formulation of a comprehensive strategy for protecting agricultural crops from pests. This synthesis also serves as a decision-making system, built on the recognition of the effectiveness of natural regulatory factors aimed at reducing populations of harmful species to economically acceptable levels, as well as levels necessary for preserving beneficial predators and parasites, taking into account the specificity of pest complexes and the dynamics of their interactions in individual agroecosystems. Integrated plant protection is harmonized with the strategy of preserving biodiversity in agro-landscapes and adjacent areas within the framework of sustainable development strategies. To implement EU strategies for biodiversity conservation and pollinator protection, precision agriculture and sustainable farming require the adoption of technologies aimed at reducing pesticide and other agrochemicals in agricultural landscapes. Biological methods of plant protection from pests, including the use of birds, play a significant role in organic farming. Birds consume a considerable amount of eggs, larvae, and adult individuals of insects, mollusks, rodents, and other pests (Kross et al., 2016), leading to natural regulation of their populations. The introduction of new bird species and increasing their numbers helps maintain the health, functional balance, development, and productivity of plant communities (Ondine et al., 2009; Smith et al., 2010; Vickery & Arlettaz, 2012; Singh et al., 2024).

Forest shelterbelts (FSB) in agrolandscapes play a crucial role in biodiversity conservation and regulating transabiotic links between plants, insects, and birds. They significantly improve the structural-functional organization and connections, increase habitat diversity, and reduce the consequences of fragmentation for biota. FSB conserve pollinators and indirectly contribute to reducing the use of agrochemicals and pesticides by increasing the abundance and species diversity of bird fauna and phytophagous insects (Perennes et al., 2023; Wesemeyer et al., 2023). However, the relationships between biodiversity (insects and birds) and landscape heterogeneity, their impact on ecosystem services, and food chain dynamics in different land use types and organic production are not sufficiently understood.

There are insufficiently studied questions regarding the interconnections and impacts of main food chain links and habitat diversity on reducing chemical loading in agro-landscapes, particularly in organic production. Additionally, mechanisms for regulating the populations of harmful organisms in agricultural ecosystems are not fully developed, and accessible and effective algorithms for agro-landscape management have yet to be established. In order to organise organic agricultural production effectively, it is necessary to study the transformation of biodiversity structure and determine the degree of ecosystem imbalance, to understand which influences and decisions lead to significant losses of ecosystem services in agrolandscapes. Therefore, **the aim of this research is**: i) To investigate the ecological, taxonomic, and functional structure of biodiversity in organic agricultural landscapes and its impact on ecosystem services. ii) To assess the risks of weed and pest penetration into agro-forestry systems. iii) To propose mechanisms for managing bird population in organic agro-ecosystems, considering biotic and transabiotic links.

2. **Study area**

The research was conducted in the agro-landscape of the Skvyra research station for organic production at the Institute of Agroecology and Environmental Management of the NAS (49.696717, 29.676318).

The agrolandscape includes fields with organic crops with an area of 40 hectares, which are surrounded by four field protective forest shelterbelts along the perimeter (Fig. 1). Soil is low-humus chernozem, coarse-grained and medium-loamy in mechanical composition on carbonate loess, characterized by a slightly weak structure (pH 6.0-6.2). These FSBs have different forestry and taxation characteristics: width, density and structure (Lavrov et al., 2021). There are also two 45-year-old fruit orchards on the territory of the agro-landscape, as well as a 50-year-old dendrological garden (4.5 hectares), in which up to 20 types of trees and more than 10 types of shrubs grow.

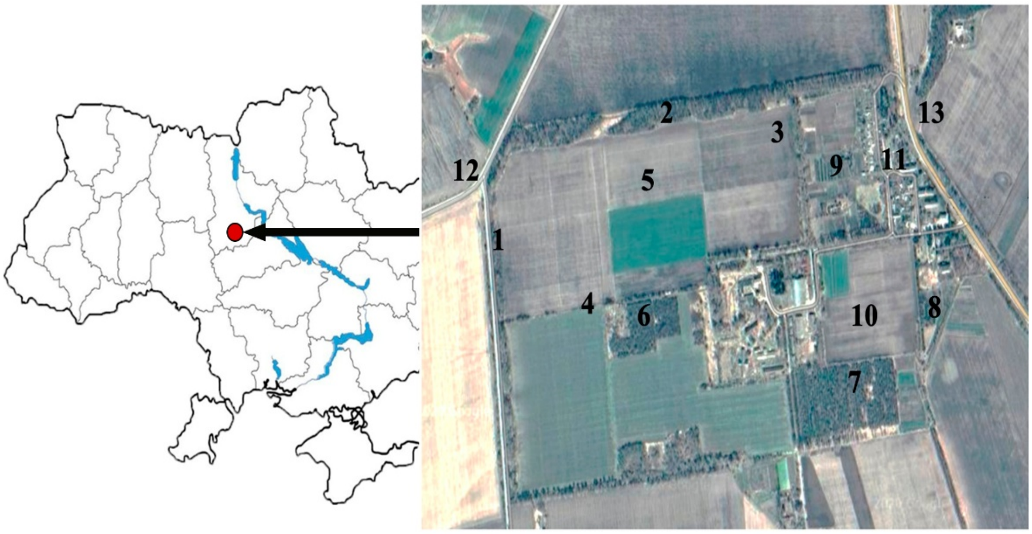

Figure 1. Agrolandscape structure of the Skvyra research station for organic production: 1,2,3,4 – forest shelterbelts, 5 – organic fields, 6,7 – orchards, 8 – dendrological garden; 9 – vegetable gardens, 10 – farmyard, 11 – station (administrative buildings), 12,13 – regional R-32 and R-18 routes

3. Material and Methods

Studies of the plant species composition, construction, were conducted using forestry and geobotanical methods (Lavrov et al., 2021). The herbaceous layer of forest belts and field margins (”FSB-field” ecotones) was investigated, taking into account the taxation characteristics of the stand. In specific areas of the forest belts, trial plots of length 100 m (on marginal edges and inside the forest belts) were established. A continuous account of the species composition was made, and assessment of the projective cover of the herbaceous layer was carried out. The botanical nomenclature was given according to WFO (2025).

3.1. Methods of insect study

Insects were caught in organic fields where soybeans (5.3 ha), buckwheat (6.3 ha) and winter wheat (5.8 ha) grew. Sampling was carried out by the standard method with an entomological aerial insect net diameter of 35 cm (10 waves in 10 equidistant field sites, altogether 100 waves with an entomological net in 10 equidistant field sites (Pokoziy et al., 2010). Recommended methods were applied to identify insects taxonomically. Correct identification of most insect species was confirmed by the head of the Laboratory of Stock Collections, I.I. Schmalhausen Institute of Zoology of the NAS of Ukraine, Doctor of Biological Sciences, Professor O.V. Putchkov (Putchkov et al., 2020) (according the keys of the European USSR (1964, 1965,1969, 1970, 1976, 1978a, b, c, 1981a, b, 1986a, b,c, 1987, 1988), as well as comparison with the stock collections). Insect species were classified by the following percentage classes to identify the level of dominance of insect species recorded during surveys: eudominants (EU) - more than 10% of the total number of individuals recorded; dominants (D) - 5.0-9.9%; subdominants (SD) - 2.0-4.9%; recedents (R) - 1-1.9%; 33 subrecedents (SR) - less than 1%.

3.2. Methods of bird study

Bird surveys were conducted in June 2019 from 6.00 a.m. to 12.00 by the common method of surveying birds along routes (Bibby et al., 2000). The organic forest belts were investigated along the perimeter of fields. The route was laid along the forest belts. The observer walked along its center. On the field, the count was carried out along the field, parallel to the forest belt in the middle of the field. All birds were taken into account to the right and left of the observer (both in the field and in the forest belt). The total length of observation routes was 3050 m. The width of the observation area depended on the width of the fragment of tree stands and ranged from 10 to 40 m in the forest belts. Therefore, avian surveys covered the entire width of each forest belt. In two fragments of gardens bordering the study field, the width of the census area was 100 m (50 m to the right and left of the observer), which is generally accepted for dense tree stands. On the field, counting was carried out over the entire width of the field, since the view through binoculars is not limited by obstacles. Thus, the area of bird population surveys totalled 6.6 hectares of forest belts along the perimeters of organic fields, 5.2 hectares of garden and 17.4 hectares of experimental fields. The species of birds were determined with Nikon Aculon A211/10x50 binoculars, and visual nest searches were conducted. Audio recordings of birds' voices (mp3) were used for acoustic identification of species. Bird nesting density (pairs/ha), its mean and standard deviation for the mean were calculated. The list of bird species is provided following the International Code of the Zoological Nomenclature (2012). Birds were analyzed by trophic groups in accordance with the food that dominates in the diet of birds (birds feeding on invertebrates, predators, phytophages, generalists and polyphages) and their foraging strategy (birds forage on the ground, plants, catch in the air in a throw from a substrate or in a soaring flight) (Blinkova & Shupova, 2018; Blinkova et al., 2020). The synanthropization index of nesting birds was estimated on Jedryczkowski (formula 1):

$$W_s = L_s/L_o, \qquad (1)$$

where L_s is the number of synanthropic species and L_o is the total number of species (Klausnitzer, 1990).

3.3. Statistical analysis

To estimate α-diversity, a Shannon Index of Diversity, Berger-Parker dominance and Pielou Species Distribution Evenness. For birds, the relative abundances of indicator species in the community were calculated. The Sørensen index was used to measure the similarity of two samples of data on crop fields (Magurran, 2004):

Shannon: $H' = -\Sigma (P_i \times \text{Ln } P_i)$; (2)

Berger-Parker: $D = N_{max}/N$; (3)

Pielou: $E_p = H'/\text{Ln } S$, (4)

Relative abundance of species i: $P_i = N_i/N$,

where S is the number of registered species for the herbaceous community or bird community (families were used for the insect community), N is the total number of individuals of all species (families), N_i is the number of individuals of each species (family), and N_{max} is the number of individuals n the most abundant species (family).

The Sørensen index was calculated by the formula 5:

$C_s = 2j/(a + b)$, (5)

where a is the number of herbaceous community or bird community species (families for the insects) present in the first group, b is the number of species (families) present in the second group, and j is the number of species (families) common to both groups. Data were statistically evaluated using STATISTICA 10 and Microsoft Excel.

4. Results

We investigated three interconnected components of biodiversity (plants, insects, birds) and their relationship with the provision of ecosystem services for maintaining landscape structure and stability, supporting ecosystems (Fig. 2). The significant biodiversity supports the functional structure of the ecosystem, including: Self-regulation, Resilience, Stability, Biotic cycling, Biotic food chains. Direct connections and influences were identified (trophic and topical links, species succession in FSB and field crops, chemical and mechanical treatments, impact of heavy machinery, noise pollution), as well as indirect ones (habitat fragmentation, hindered species migration due to disturbance factors, expansion of alien plant species through seed dispersal and plant parts).

4.1. Analysis of the herbaceous layer

We found that the numbers of annual and perennial herbaceous species were very similar among the FSBs. In total, 102 vascular plants from 32 families and 85 genera were found in the herbaceous layers of forest belts. In the distribution of species among classes, *Liliopsida* accounted for 14.7%, *Magnoliopsida* accounted for 83.3%, and the overall ratio of *Liliopsida*:*Magnoliopsida* was 1:6. The class *Polypodiopsida* was represented by 2 species, *Equisetum arvense* L. and *E. fluviatile* L.

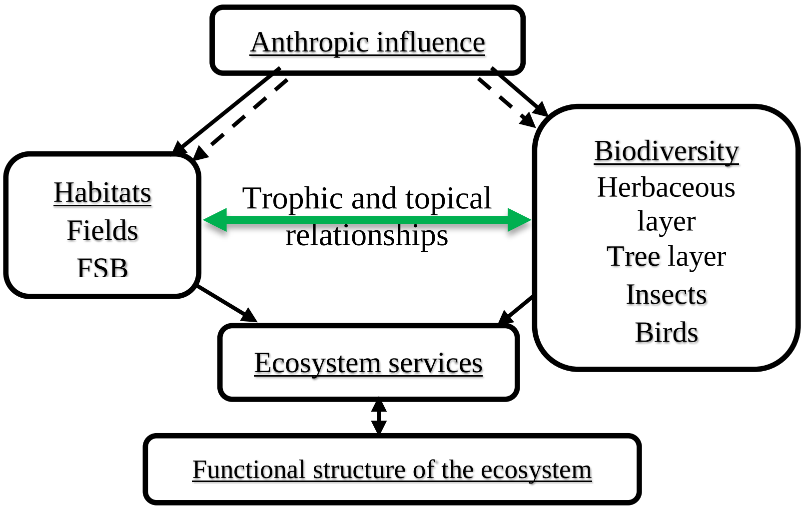

Figure 2. A scheme for maintaining ecosystem services of agricultural landscapes through three biodiversity links, where direct links: ⟶; indirect links: - - - ➝

From 49-54% of all studied herbaceous plants were ruderal plant component; forest plant component were barely half as many. The alien component of the flora accounted for 24.5% (n = 32), which indicates a significant secondary anthropogenic transformation of ecotopes. Under the canopies of plantations grow quarantine weeds (*Sonchus arvensis* L., *Setaria pumila* (Poir.) Roem. & Schult., *Melandrium album* (Mill.) Garcke, *Portulaca oleracea* L., *Stellaria media* (L.) Vill., *Thlaspi arvense* L.), plants that have escaped from cultivation (*Raphanus sativus* L., *Cannabis sativa* L., *Fagopyrum esculentum* Moench), and invasive alien transformer species (*Ambrosia artemisiifolia* L., *Impatiens parviflora* DC., *Conyza canadensis* (L.) Cronquist, *Cyclachaena xanthiifolia* (Nutt.) Fresen., *Asclepias syriaca* L., *Reynoutria japonica* Houtt.). This last species is listed in the category of most dangerous invasive species by the International Union for Conservation of Nature.

Ranked first among the 10 leading families of herbaceous plants, as in most galarctic floras (Tarasov, 2012), *Asteraceae* was represented by 22 species or 21.6% of the total number of species. *Poaceae* (15 species, 14.7%) was in second place, *Brassicaceae* was represented by 6 species or 5.9%, *Fabaceae* and *Polygonaceae* by 5 species or 4.9% each, and *Caryophyllaceae* and *Lamiaceae* by 4 species (3.9%) each. Five families were represented by 3 species or 2.9% and 14 families by 1 species (1.9%), almost all of which were alien archeophytes and/or quarantine weeds (*Portulaca oleracea* L., *Amaranthus retroflexus* L., *A. syriaca*, *Fumaria officinalis* L., *Anagallis arvensis* L. (ANGAR)). Representatives of the families *Vitaceae* (*Vitis vinifera* L.) and *Polygonaceae* (*Fagopyrum esculentum* Moench) are escape species from crops. The 7 most prominent families accounted for 59.8% (61 species) of the total number of species. The dominance of the family *Poaceae* is characteristic of most floras of the Holarctic and typical for the flora of Ukraine. *Urticaceae* occupied sixth place and *Plantaginaceae* seventh place in the family spectrum at the FSBs studied. These families were not peculiar to the 10 leading families of the compared flora. The family *Apiaceae* in the FSBs occupied a relatively high 7th place, which contradicts the abovementioned floristic data and approaches the ranking in the synanthropic flora of Ukraine. *Polygonaceae* and *Euphorbiaceae* occupied 4th and 6th places, respectively, while in other floras, they are not included even in the first twenty families.

The family spectrum reflects the most common features of a flora, while taxonomic units of lower rank are more dependent on environmental conditions. Therefore, *Poa* L. (4 species); *Urtica* L., *Trifolium* L., *Euphorbia* L. (three species each); and *Cannabis* L., *Equisetum* L., *Geranium* L., and *Plantago* L. (two species each) exhibited the highest species richness in the generic spectrum. The remaining genera were represented by one species each. Seven weed species were detected in organic crop fields, five for each organic crop (Table 1). Their total density increased four times from wheat to buckwheat to soybean.

S. viridis L., *Echinochloa crus-galli* L., and *Chenopodium album* L. were found in soybean crops and the margins nearby. In organic winter wheat and the adjacent margins, only one common species, *C. album* L., was found. On the other hand, the common species *C. album* L. and *E. crus-galli* L. were found in organic buckwheat and the margins nearby. All these species were present in the adjacent FSBs.

Table 1. Species composition of weeds in crops (individuals × m^{-2}).

Species	Winter wheat	Buckwheat	Soybean
Amaranthus retroflexus L.	6.2	8.2	2.7
Setaria viridis (L.) P. Beauv.	9.6	7.7	57.3

Echinochloa crus-galli L.	-	11.1	32
Polygonum persicaria L.	-	2.1	29.3
Chenopodium album L.	8.7	16.6	10.7
Sonchus arvensis L.	1.3	-	-
Equisetum arvense L.	6	-	-
Total	41.8	45.7	132.0

Values of the Shannon diversity index for herbaceous layer increased with approach to the FSBs; in the margins, values ranged from 0.2-0.8, greater than those in the middle of the fields (Table 2). The largest difference was found in the "winter wheat – northern forest shelterbelt" ecotone, as these ecotones and FSBs are the widest (15 m and 35 m, respectively). The Shannon index for the herbaceous layer of this FSB was 2.5-2.8 times higher than values in the middle of the field. Pielou's evenness index ranged from 2.1-2.2 irrespective of the study area. Thus, herbaceous diversity increased, and species dominance decreased, in the ecotone with increasing proximity to the FSB, as indicated by the value of the Berger-Parker index.

Table 2. Diversity indices for herbaceous in crop fields and forest shelterbelts.

Index	**Soybean** inside field	**Soybean** at margins	**Winter wheat** inside field	**Winter wheat** at margins	**Buckwheat** inside field	**Buckwheat** at margins	**FSB total**
Shannon diversity	1.51±0.08	1.90±0.1	1.73±0.08	2.51±0.07	1.63±0.08	1.79±0.08	4.20±0.14
Berger-Parker dominance	0.30±0.02	0.21±0.01	0.22±0.01	0.11±0.01	0.23±0.01	0.20±0.01	0.03±0.01
Pielou evenness	2.10±0.16	2.22±0.12	2.20±0.13	2.20±0.12	2.33±0.16	2.11±0.16	2.09±0.12

4.2. Analysis of the insect community

Organic fields were characterized by high taxonomic diversity of insects. Seven orders were registered: *Coleoptera*, *Diptera*, *Hemiptera*, *Hymenoptera*, *Lepidoptera*, *Neuroptera* and *Thysanoptera*, altogether 31 families. The most numerous were *Diptera* (140 individuals) and *Hymenoptera* (127 individuals). The least numerous were *Lepidoptera* and *Thysanoptera*, which numbered 10 individuals each (Fig. 3). The total number of insects in the field with organic winter wheat was 62 individuals/100 passes. Representatives of 14 families were found; they were dominated by scarab beetles (*Scarabaeidae*, 22.6%), leaf-miner flies

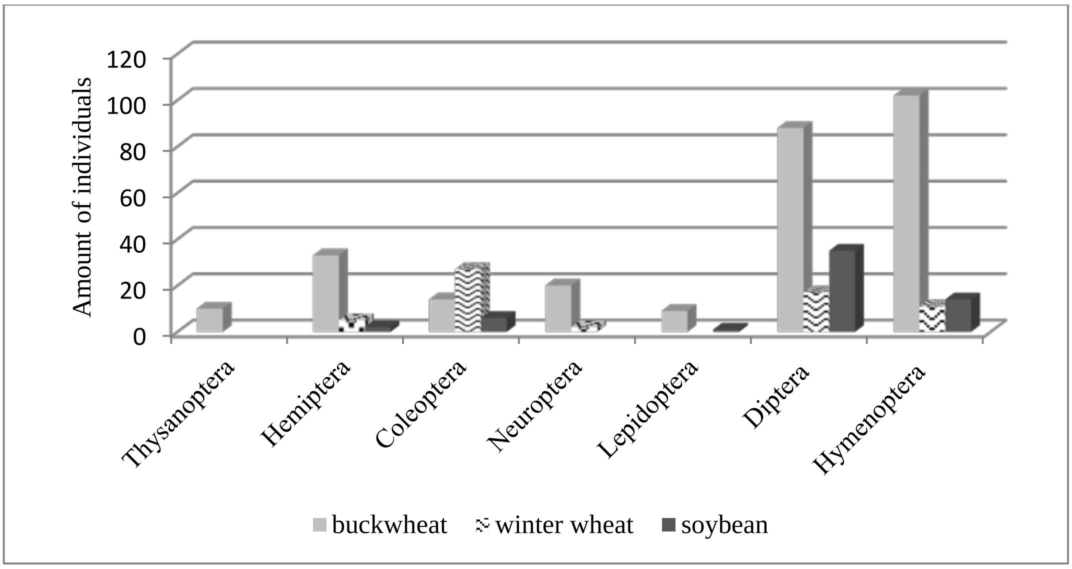

Figure 3. Distribution of insects by orders in agricultural fields

(*Agromyzidae*, 14.5%) and chalcidoid parasitic insects (*Chalcidoidea*, 14.5% of all insects caught). The shares of 11 families *Anthocoridae* and *Scutelleridae* (*Hemiptera*); *Cantharidae, Chrysomelidae, Coccinellidae, Curculionidae* and *Latridiidae (Coleoptera); Braconidae (Hymenoptera); Cecidomyiidae* and *Syrphidae (Diptera);* and *Chrysopidae* (1.6%) ranged from 1.6 to 9.7% of all families found in the fields.

The entomofauna of organic buckwheat fields proved to be the richest in quality and quantity. The number of insects averaged 276 individuals/100 passes, four times as many as in other fields. They were taxonomically represented by 22 families dominated by bees (*Apidae*, 21.4%) and grass flies (*Chloropidae*, 15.9% of the total amount). The shares of other families A*gromyzidae, Anthomyiidae, Syrphidae, Tachinidae* and *Tephritidae (Diptera*); *Rhopalidae, Anthocoridae* and *Miridae (Hemiptera); Braconidae, Halictidae, Megachilidae, Sphecidae, Tenthredinidae* and *Chalcididae (Hymenoptera); Coccinellidae, Elateridae* and *Nitidulidae (Coleoptera); Chrysopidae (Neuroptera); Thripidae (Thysanoptera);* and *Plutellidae (Lepidoptera)* accounted for 0.4–8.7% of the total entomofauna of the field.

Among the insects of the organic soybean field, representatives of 15 families were identified, among which the true flies *Agromyzidae* (32.8%) dominated, with *Anthomyiidae* also prominent (13.8%) and order *Hymenoptera* represented by *Chalcididae* (13.8%) and *Braconidae* (10.3%). The shares of beetle families *Chrysomelidae, Coccinellidae, Curculionidae and Scarabaeidae;* fly families *Cecidomyiidae, Syrphidae, Tephritidae and Chloropidae;* capsid bugs in *Miridae*; cicadas (*Cicadelidae*); and lepidopterans in *Nymphalidae* ranged from 1.7 to 9.9%. The number of insects was the lowest among all organic crops studied, 58 individuals / 100 passes. There were three families of eudominant insects, two dominant families in winter wheat, two and five in buckwheat, and four and one families in soybean (Appendix 1). The greatest number of subrecedents (seven families) were buckwheat. The average number of individuals in a family ranged from 4-13; the medians were 3, 9, and 2 in winter wheat, buckwheat and soybean, respectively (Fig. 4), a pattern confirmed by the diversity indices. The most highly represented family (*Apidae*) numbered 59 individuals. Insect phytophages (40-69% of the total entomofauna), which feed on crops and other plants (weeds), dominated trophic specialization. Parasitic species ranged from 18 to 24%, and predators ranged from 7 to 26% of the total number of insects. Other groups (saprophages, pollinators) were encountered sporadically and not in all fields. It should be noted that the crop pests were represented by some species from the families *Agromyzidae, Chloropidae, Chrysomelidae, Curculionidae, Nitidulidae, Scarabaeidae, Cicadellidae* and *Scutelleridae.* In the winter wheat field, some flea species from the genera *Chaetocnema*, *Anisoplia austriaca* Herbst and *Eurygaster maurus* L. were numerically dominant; in the buckwheat field species from genera *Meligethes* and *Athalia rosae* L. were found; and in the soybean field, *Oulema melanopus* L., *Sitona lineatus* L. and *Anisoplia austriaca* dominated.

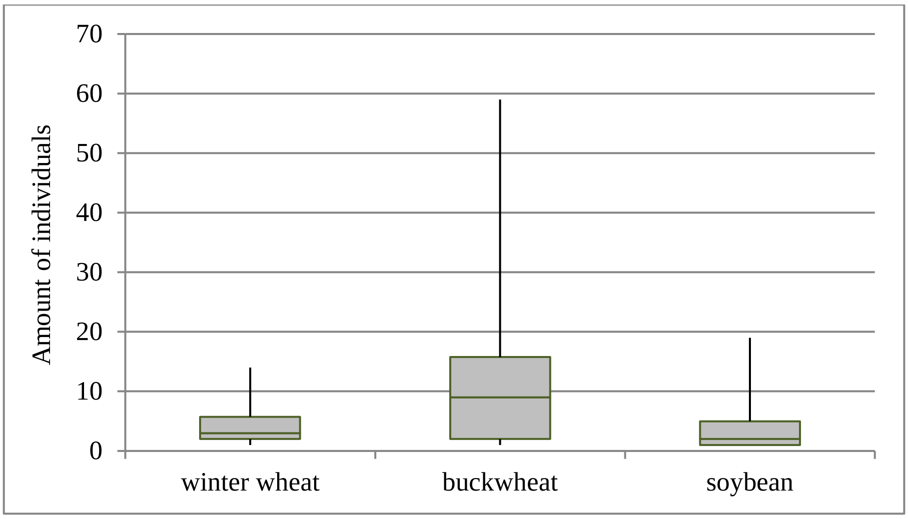

Figure 4. Number of insects in families at crops

Among the phytophages of other plants, mainly representatives of the families *Chrysomelidae, Curculionidae (Coleoptera), Tephritidae (Diptera), Rhopalidae, Miridae (Hemiptera), Tenthredinidae (Hymenoptera)* and *Nymphalidae (Lepidoptera)* were recorded. Among predators, representatives of the families *Anthocoridae* (the genus *Orius*), *Chrysopidae* (*Chrysopa* sp.), *Coccinellidae* (mainly species of the genera *Coccinella* and *Propylea*), and *Syrphidae* (dominated by the species *Sphaerophoria scripta* L.) were registered in all fields. Among the parasitic insects were *Braconidae* and *Chalcididae (Hymenoptera)* and *Tachinidae*

(Diptera). Saprophages (mainly the genus *Lathridius, Latridiidae*) were most commonly found in winter wheat crops. This may be because during the winter period, vegetative litter accumulates in the field, which attracts saprophages. In other fields, there was no litter, and accordingly, saprophages were absent from our list. Pollinators were found only in buckwheat (representatives of the families *Apidae, Halictidae and Megachilidae*), although flowers were also present on soybeans. It is likely that the absence of pollinators in the soybean field was due to the fact that this crop is self-pollinating, so its flowers do not attract insects.

4.3. Analysis of the bird community

In total, 44 bird species were identified in the study area, 39 of which were nesting (34 in tree stands surrounding the fields and 5 in the organic experimental fields). The taxonomic diversity of nesting birds of FSBs included 6 orders, 15 families and 26 genera. Only representatives of *Galliformes* and *Passeriformes* nested in the study fields. Another 5 species, representing 3 orders, 4 families and 5 genera, visited the organic fields to feed from remote biotopes. Among the identified species, 31 are protected by the Bonn or Bern Conventions, 8 are protected by both of these Conventions, and 2 are additionally listed at the level of the Washington Convention and the Red Book of Ukraine. Thus, 93.2% of the bird species (n = 44) that used experimental organic crops or adjacent biotopes for nesting or foraging are rare at one level or another.

The average nesting density of birds in tree plantations located along the perimeter of organic fields was generally 0.45 ± 0.07 pairs/ha. In forest belts, it was higher than the average, 0.65 ± 0.1; in gardens, it was lower, 0.36 ± 0.05 pairs/ha. The nesting density of birds in the fields was quite low, 0.28 ± 0.00 pairs/ha, which reflects the low number of species, each of which was represented by 1-2 pairs. In tree stands, *Parus major* L. (2.07 pairs/ha, P_i=0.136), *Turdus merula* L. (1.07 pairs/ha, P_i=0.071), *Fringilla coelebs* L. (0.99 pairs/ha, P_i=0.065), *Erithacus rubecula* L. (0.99 pairs/ha, P_i=0.060) dominated by abundance.

Galerida cristata L. and *Motacilla flava* L., each with a density of 0.04 pairs/ha (P_i=0.286 for each species), dominated in the organic fields. Nesting density and relative abundance in the nesting bird community of the field for *Coturnix coturnix* L., *Alauda arvensis* L. and *Anthus pratensis* L. was 0.02 pairs/h and P_i = 0.143, respectively.

Nesting birds belonged to three ecological groups. Campophiles (12.8%) inhabited the fields, and dendrophiles (79.5%) and birds associated with sclerophylls (7.7% of the total species list) were found in tree stands. The α-diversity of the nesting communities of tree plantations showed high Shannon and Pielou indices with low indices of dominance (Fig. 5).

For the communities of birds nesting in the organic fields, the evenness of distribution of species abundance was also high. Nevertheless, the indices of diversity and dominance were less favourable, and their ratio varied less than in tree plantations.

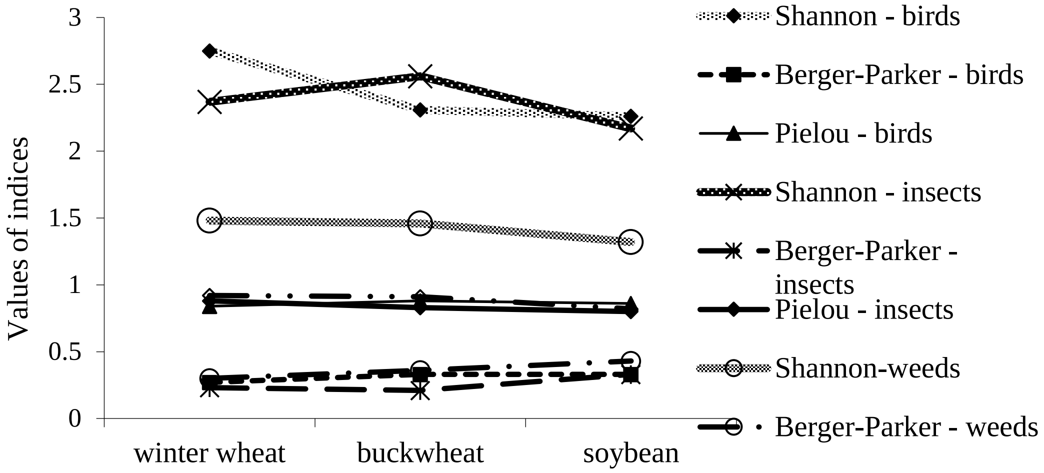

Figure 5. α-diversity of weeds, insects and birds communities in the fields with organic crops

The gradient of synanthropisation of nesting birds is from lower to higher: 0.2 in the experimental fields, 0.8 in the FSB, and 0.9 in the gardens.

In total, birds of 5 trophic groups were noted at the study sites, the least numerous of which were polyphages (2.3%), represented by *Corvus corax* L., arriving from other biotopes in search of food. Predators of birds were represented by 2 species (4.5%), *Milvus migrans* Boddaert and *Circus pygargus* L. The largest share of bird species (47.7%) that fed in the research fields and FSBs consisted of generalists eating various invertebrates, fruits, and green parts of plants. In total, 83.7% (n = 41) of all registered species catch certain invertebrates. Classified by foraging strategy, 4 species, *Oriolus oriolus* L., *Sitta europaea* L., *Certhia familiaris* L. and *Coccothraustes coccothraustes* L., were associated only with tree plantations; 3 species, *Apus apus* L., *Hirundo rustica* L., and *Delichon urbica* L., catch insects in the air relatively high above the phytocenosis; and the other 37 species used field biotopes to various degrees. The species best representing this guild were *C. pygargus*, *C. coturnix*, *G. cristata*, *A. arvensis*, *A. pratensis* and *M. flava* – campophiles that inhabit open biotopes. 13 species are associated only with tree plantations, the rest used field biotopes in varying degrees. Birds of 31 species used fields and tree biotopes for feeding. These included birds that feed mainly on invertebrates, granivorous and generalists. In general, these species constitute a beneficial natural factor in the reduction of many phytophages; granivores and birds with varied diets reduce the amount of ruderal-segetal vegetation as they eat the seeds of plants *Taraxacum* F.H.WIGG., *Plantago* L., *Sonchus* L., etc. The identified predators of birds *M. migrans* and *C.*

pygargus mainly eat small rodents (*Rodentia*), and the diet of *M. migrans* is supplemented by large insects with hard coverings that small birds are not capable of catching. Such insects are also eaten by *Lanius collurio* L., *Lanius minor* J. F. Gmelin, *C. corax*, *Passer domesticus* (L.), and *P. montanus* (L.). Birds such as *L. collurio, L. minor*, and *C. corax* eat small rodents, when possible. A promising sign was the presence of *Cuculus canorus* L. in the research territory, since the specificity of its digestive system anatomy allows this species to feed on larvae of the genus *Lymantria*, which birds of the order *Passeriformes* do not eat.

The most eurytopic birds are those that gather food from trees, herbaceous plants and the ground. They all use a broad range of feeding locations and can easily move from one to another. Thus, *F. coelebs, Acanthis cannabina* L., *Sylvia atricapilla* L., *Sylvia borin* Boddaert, *Sylvia communis* Latham, *P. domesticus, P. montanus, Emberiza citrinella* L. and *E. hortulana* L. feed on and nourish fledglings with various species of *Chrysomelidae, Curculionidae, Nymphalidae* and *Chloropidae* at different stages of development, which prevents outbreaks of these phytophages. These are birds that favour ecotone sites. *Phylloscopus collybita* Vieillot, *P. sibilatrix* Bechstein, *Ficedula albicollis* Temminck, *Muscicapa striata* Pallas, *Phoenicurus phoenicurus* L., *E. rubecula*, *Luscinia luscinia* L., *P. major* and *Carduelis carduelis* L. feed on smaller insects *Aphididae, Cephidae, Plutellidae* and *Cicadellidae*) as well as *Gastropoda*. *F. albicollis* and *Ph. phoenicurus* catch flying insects, for example, representatives of *Diptera*, in the air above the plants. In contrast, *T. merula* and *T. philomelos* C. L. Brehm forage in the terrestrial layer and the upper soil layer, catching larvae of large insects, slugs, and worms.

4.4. Relationships between organic crops and weeds, insect and bird communities

To find the connections in organic agro-landscape systems, it is advisable to consider the food dependencies on the different levels, where the secondary and tertiary consumers are easily accessible for visual observation by birds. Visitation of a field by birds for feeding depends not only on the forage base of the field but also on the species composition of the bird groups nesting in the field and in the surrounding tree plantations. Of the 31 bird species described above, 28 species feed in organic fields: 26 in wheat, 14 in soybean and 14 in buckwheat. It is important to note that the large birds *M. migrans*, *C. pygargus* and *C. corax* were represented by only one individual from each species, which circled above all the fields, searching for prey. These are birds characterized by large foraging areas of which fields of 5-6 hectares occupy a small share. *G. cristata* and *M. flava*, which were the dominant field-nesting species, were distributed throughout the organic crops. The taxation characteristics of the forest shelter belts and the distances at which they are located from the field directly impact the quantitative composition of birds. Birds use fields in agro-landscapes to search for food and forest belts for nesting. Due to the distance of the soybean field from the forest belts, only 5 species nesting in tree stands. These included two species, *M. migrans* and *L. collurio,* with large foraging areas, and three species, *Ph. phoenicurus*, *E. rubecula* and *E. citrinella,* with nesting areas in the garden. Instead, the greatest number of birds living in forest belts (n = 17) fed in the winter wheat field protected by the forest belt providing the most shelter, No 2. Among these, 11 species do not have large forage areas. On the other hand, the buckwheat field was visited by an intermediate number of dendrophiles – 9 species, 5 of which have small forage areas. The reason for this is the not-so-wide field of buckwheat bordering forest belt No 1 and the less amenable qualitative characteristics of the forest belt relative to the nesting area. We found that the α-diversity differed slightly between insects and birds in the organic crop fields: the Shannon species diversity index showed significantly higher values for birds than for insects in winter wheat and soybean fields. In the soybean field, the diversity of birds and insects was similar, but the species diversity of birds was higher (Fig. 5). For the insects communities, no significant variation in the Shannon index was detected among fields. Its value was slightly higher in buckwheat (2.56) and wheat (2.37) than in soybean (2.17). This may indicate a relatively even ratio of most taxonomic groups of insects among different crops. We attribute the elevated insect species diversity in the buckwheat field to the attractiveness of this crop for insects with different food specialities and pollinators, which led to an increase in species and quantitative composition in comparison to other crops. The highest values of the Shannon index for the birds communities were observed in the winter wheat field due to the greatest number and abundance of feeding birds being in this field. For the plants complex, the Shannon index values were much lower than for the complexes of the studied animals. The diversity of weeds was lower than that of birds and insects, as weed numbers are regulated by humans.

In the insects communities, the Berger-Parker dominance index was highest in the soybean field (0.33), since insects in this field were dominated by representatives of one family, *Agromyzidae* (up to one third of the entomofauna). For birds, the values of this index were slightly higher in the buckwheat field and were very similar in other fields to values for insect communities. The Berger-Parker index was greatest for all three types of communities in the organic soybean field. It is likely that the pressure of the dominant *Setaria viridis* (L.) P. Beauv. (57.3 individuals/m^2) in the soybean field attracted representatives of the family *Agromyzidae*, which in turn attracted entomophagous birds such as *A. pratensis*, *M. flava*, *F. albicollis*, *Ph. phoenicurus* and *E. rubecula*, the total relative abundance of which was twice as large as in the organic winter wheat field. The oscillation curve of the values of the Berger-Parker index in the various fields was most even for the birds communities.

Numbers of weeds and insects gradually decreased from winter wheat to buckwheat to soybeans. However, numbers increased for the birds that feed in the study area, although all the Pielou index values were sufficiently high.

The complex of segetal vegetation for the pairs winter wheat-buckwheat and winter wheat-soybean showed the same Sørensen index values (0.60). The weed species in the soybean and buckwheat fields were identical, so their similarity index was 1.0. The values of the Sørensen index for the winter wheat-buckwheat pair differed significantly between the entomo- and bird community (Table 3). For winter wheat-soybean and buckwheat-soybean, similarity index values were identical for the entomo- and bird community. The similar values of bird community β-diversity among the fields resulted from their physical proximity to each other. These fields are small in area; the birds that feed in them nest close by. The variation in Sørensen index values for the insect communities in the fields was caused by the small number of families that are not typical for these crops. The degree of insect communities similarity in buckwheat and soybeans was due to the use by anthomyiid larvae of leaves of *Polygonum persicaria* L., which is common in these fields. Since soybeans, winter wheat are self-pollinated crops, they share the greatest number of insect families, which are attracted not by the smell but by the deposition of larvae in different topical stations.

Table 3. Similarity of the weeds, insects and birds communities in the fields with organic crops according to Sørensen index (Cs_{weeds} / $Cs_{insects}$ /Cs_{birds}).

Crop	Winter wheat	Buckwheat	Soybean
Winter wheat	–	3 / 7 / 14	3 / 9 / 12
Buckwheat	0.60 / 0.39 / 0.70	–	5 / 9 / 7
Soybean	0.60 / 0.62 / 0.60	1.0 / 0.50 / 0.50	–

Explanation: The lower left corner is the Sørensen index; the upper right corner is the number of taxa.

Phytophages prevailed in insect communities in all organic crops (Fig. 6). From 7 to 47% of the quantitative composition consisted of predators, parasites and saprophytes, that is, species that do not cause damage to crops. Considering insect pollinators, 31-60% of the quantitative composition of communities is more useful in the organic farming system than harmful: they destroy phytophagic pests and process litter into substances that are more accessible for assimilation by plants. In buckwheat, complete dominance of pollinators was observed.

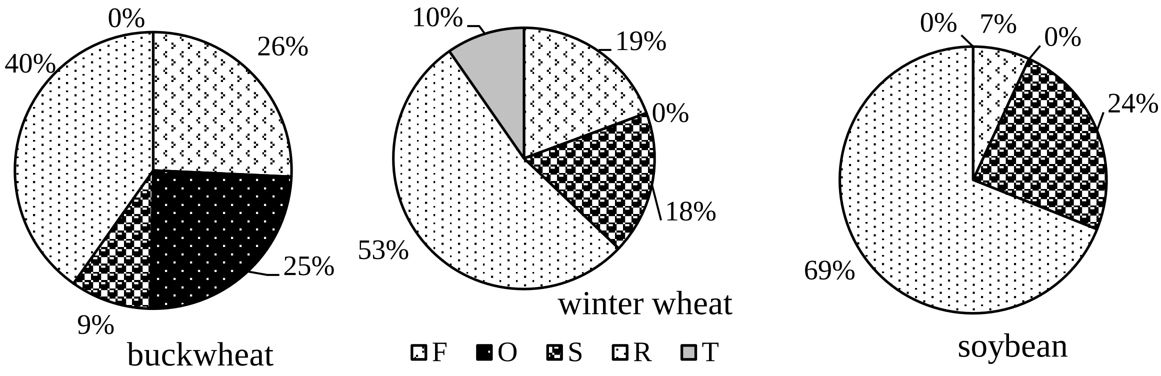

Figure 6. Distribution of insects in the organic fields by functional specialization (%): F – predators, T – saprophages, R – phytophages, S – parasites, O – pollinators

For bird communities, the species composition and relative abundance of birds with mixed diets prevailed in all fields (Fig. 7, Appendix 2). For example, during the fledgling feeding period (May – July), the share of species that eat insects reached 73-86%, and that of individuals reached 84-86%. On the other hand, the species composition in ornithocomplexes of phytophages that can also eat crops was 7-15%, and the number of individuals was 7-12%.

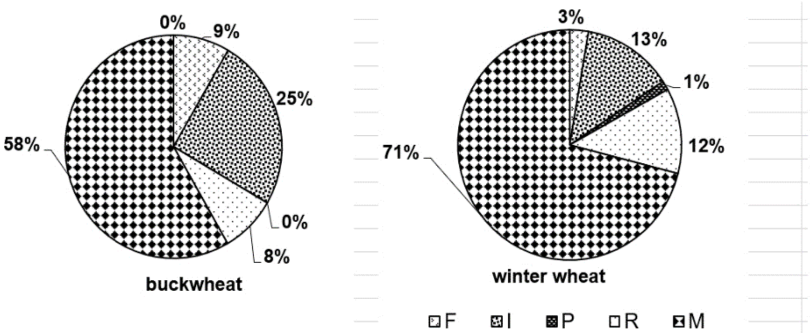

Figure 7. Distribution of birds in organic fields by types of feeding (%): F – predators, I – entomophages, M – generalists, R – phytophages, P – polyphages

Functional relationships between three groups of organisms are traced (Fig. 8). It is shown that taxonomic and species biodiversity increases with the complexity of landscape structure (from fields with monocultures to FSB), leading to a decrease in alien plant species contamination and synanthropization of birds. Insectivores and herbivorous species were displaied to birds and insects. The insectivores group for insects is simultaneously predators.

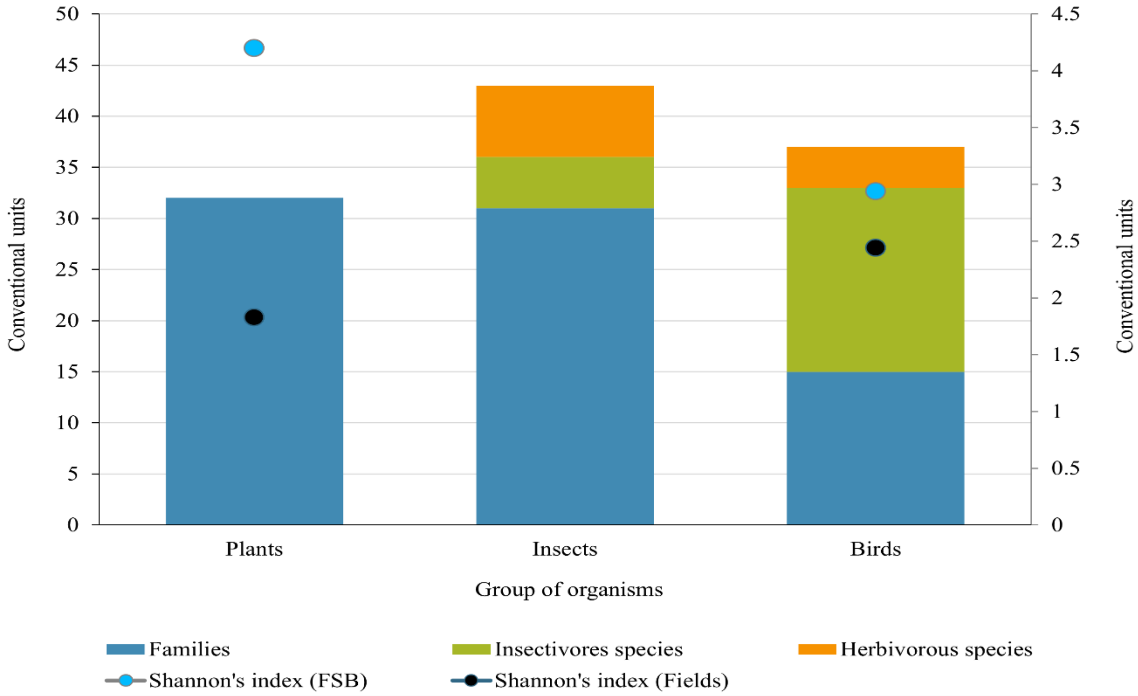

Figure 8. Indicators of functional links and food chains in the agricultural landscape

5. Discussion

The European Union's policy on landscape conservation and management underscores the necessity of preserving ecosystems as natural capital for biodiversity conservation and human well-being (Manton et al., 2019). Since the hierarchical structure of the system influences the assembly and repair of the system, integration is the primary determining factor of such a process (Nehaniv & Rhodes, 2000). Therefore, the better-developed the biodiversity structure, the more stable the agroecosystem and its ability to recover in case of environmental quality decline (intensive land use, monocultures, pesticide and fertilizer application, etc.). The connectivity of green and blue infrastructure fragments, their sufficient quality and size at the landscape and ecosystem conservation level, is of great importance (Manton et al., 2019; Graviola et al., 2022). The trophic, topical, and other biodiversity connections are crucial for understanding, supporting, and conserving biodiversity in ecosystems.

Spontaneous vegetation in agro-landscapes plays both a positive role (in ecosystem stability and biodiversity preservation) and a negative one for humans, such as the spread of weeds and a decrease in crop yields. However, plant species diversity serves as an indicator of ecosystem stability (Lavrov et al., 2021). In the studied agro-landscape, the vegetation exhibits an imbalanced systematic structure, yet biodiversity indices are high, especially in the field margins. Seven weed species typical for this type of crop are present in the fields. It has been demonstrated that biodiversity indices of the herbaceous layer increased along the gradient from fields to margins to FSB. Plant invasions are considered one of the major threats to biodiversity, with half of the species in the studied habitats being non-native, including six invasive transformer species in the environment (*A. artemisiifolia*, *A. syriaca*, *C. canadensis, C. xanthiifolia*, *I. parviflora*, *R. japonica*).

The insect population has declined by 70-80% over the last decades in more than 20 studies in temperate climate zones. Such a decline in insect abundance has negative consequences for other taxa at higher trophic levels, such as predators and parasites (Bailon et al., 2022), and also contributes to the global process of plant invasions. Urbanization, climate change, pesticides, and fertilizers are probable reasons for the reduction in insect populations. The prospects of using insects for biological control to reduce the use of agrochemicals in agro-landscapes have been explored (Bailon et al., 2022; Teofilova, 2022).

Some species of *Insecta*, especially epigeic groups *Hymenoptera* and *Coleoptera* were suitabled for bioindicative assessment of landscape conditions, under influencing the urbanization gradient from urban to rural landscapes (Langraf et al., 2021). In studies conducted solely in rapeseed fields, 36 species of ground beetles (*Coleoptera: Carabidae*) were found. They are considered an important group of beneficial insects known for their contribution to limiting pest activity and stabilisation environmental (Teofilova, 2022). In our research, the diversity of insects includes 7 orders and 31 families, which are high indicators. Among them, 8 families are classified under *Coleoptera*. It is important to note that among the pollinator insects, especially in buckwheat fields, bees predominated (*Apidae*, 21.4%), which is an important characteristic of ecosystem stability and indicates the effectiveness of organic farming in preserving pollinator species. Therefore, the distribution of biodiversity, especially plants and insects, is an indicator of the effectiveness of pollinator services in the agro-landscape.

With increasing land use intensity and disturbing factors, the number of predatory birds in landscapes decreases (Manton et al., 2019). Similar processes were observed in our study in the organic agro-landscape.

Our study, like the previous ones (Kuzmenko, 2011), showed that the birds that nest directly in the fields are not numerous. Nesting in shrub fragments *L. collurio, L. minor, S. borin, S. communis, C. carduelis, A. cannabina, E. citrinella, E. hortulana* are the most massive destroyers of phytophages in the field, and birds of the genus *Sylvia* are the main hosts, on which *Cuculus canorus* parasitizes. The specificity of the anatomy allows *C. canorus* to feed on larvae of the genus *Lymantria*, which are not eaten by birds of the *Passeriformes* order. With the increasing diversity of plants in the organic agro-landscape, the abundance, richness of entomophages and birds increases (Power et al., 2016). Most of them are relevant for nesting in adjacent FSBs to prevent outbreaks of phytophagous invertebrates.

The most important approach for attracting birds is to create comfortable conditions for their nesting. During the reproductive period, most birds have small foraging areas because the need for the parents to conserve time and energy encourages the birds to collect food for nestlings as close to the nest as possible. Forest monocultures are characterized by low species richness and, accordingly, low diversity of stands and few ecological niches, reducing avian population density (Felton et al., 2016). The absence of undergrowth also harms birds, nesting, and foraging in shrubs (Camprodon & Brotons, 2006). It was revealed that bird biodiversity increases depending on the species diversity of trees and shrubs (Söderström et al., 2001). Forest belts will fully ensure the presence, development and migration of insects if the diversity of tree and shrub species is brought to a scientifically sound level and combined into a single system (Vahaliuk et al., 2016). We believe that it is necessary to create agro-landscapes of complex composition and structure with multilayers stands of different configurations and purposes. This provides a broader range and number of nest sites per unit area of FSB, which is the basis for increasing the representation of dendrophilous birds. It also reduces intra- and interspecific competition among birds, increasing the number of nesting pairs per unit area of forest plantation. To protect birds from various hazards and to realize their reproductive function, it is necessary to create dense shrub layers in forest belts. In such shrub fragments, *L. collurio*, *L. minor*, *S. borin*, *S. communis*, *C. carduelis*, *A. cannabina*, *E. citrinella*, and *E. hortulana* nest. Birds of the genus *Sylvia* are the main hosts parasitized by *C. canorus*; therefore, their attraction is especially relevant. *T. merula*, *T. philomelos*, and *F. coelebs* are eurytopic in selecting woody plants for breeding (Chaplygina, 2009, 2015) and are cavity-nesting birds. However, they are eurytopic, depending on the presence of hollows and other cavities in tree trunks.

In agro-landscapes, the diversity of ecological conditions is limited (Kuzmenko, 2018), so the occurrence of red-listed bird species is very important for the sustainable development of agro-landscapes and ecosystem services for biodiversity conservation. Particular attention should be given to agricultural fields as foraging locations for predatory birds such as *M. migrans* and *C. pygargus* (including those identified by our observations). Organic farming in this sense is essential because harmful substances accumulating in food chains lead to the death of animals on the top of the trophic pyramids. The low species diversity and abundance of birds found within our study in organic fields are generally normal, as noted by Shaffer and DeLong

(2019). FSBs were dominated by *P. major*, *T. merula*, *F. coelebs* and *E. rubecula*, which are typically dominant species in the plantations of the region (Blinkova & Shupova, 2018), and the field dominants were *G. cristata* and *M. flava,* the most common birds nesting in the conventional fields of the forest steppe (Kuzmenko, 2011). Under conventional farming, the similarity of the avifauna of buckwheat and soybean fields is significantly higher than the similarity with the bird communities of cereal crops (Kuzmenko, 2018). For organic fields, we found that the similarity of bird communities of buckwheat and soybean fields is significantly higher than the similarity with the communities of winter wheat fields.

Predatory birds nest in the fields and meadows on the ground, so one should cultivate the fields carefully to prevent the death of nestlings. The representative of this group is *C. pygargus,* which arrives to hunt in the field. *M. migrans*, *Buteo rufinus* Cretzschmar, *B. buteo*, *Falco vespertinus* L., *F. tinnunculus* L. and others are also desirable to attract to agro-landscapes. Nesting of such species as *Pica pica* L. and especially *Corvus frugilegus* L., whose nests are a resource for other nesting bird species (predators and owls), is valuable.

To improve bird habitat on small farmland it is necessary to maintain a wide range of habitat types and reduce hunting pressure (Pringle et al., 2019). To increase the biodiversity of agricultural lands as a whole, biotopes of forests, FSBs, shrubs, and ponds must cover at least 20% of the landscape (Frei et al., 2018). The presence of heterogeneous agricultural landscapes contributes to the diversity of plants, arthropods, birds, other animals (Ondine et al., 2009; Vickery & Arlettaz, 2012); pollination of plants; and other essential ecosystem services (Bennewicz & Barczak, 2020). This is due to the developed structure of different types of phytocenoses, food chains and interspecies relationships.

Thus, organic agriculture and the specified landscape gradient (field, field margins and seminatural tree plantations) achieve significant biodiversity of taxa, which contributes to increasing the quantity and quality of ecosystem services for pest control, pollination of these plants, and conservation of food chains. It is essential to consider the structure and layering of FSB, planting tree species that can serve as food sources and shelters for birds, and preserving dead trees within the FSB. Diversifying habitat types through the expansion of ecotones and utilizing plants resistant to damage by phytophagous insects in fields are crucial measures. Organic landscape management strategies should integrate the attraction and conservation of bird populations as a viable method for pest control, alongside other economic, ecological, and organic farming strategies aimed at preserving biodiversity and promoting sustainability.

6. Conclusion

We investigated the transbiotic relationships among plants, insects, and birds to improve agro-landscape management and biodiversity conservation. We found that the plants diversity increases while species dominance decreases in ecotones approaching forest belts. The diversity of insects depends on the crop planted in the fields, and bird diversity is influenced by landscape connectivity and structure. We constructed food chains "weeds - insects - birds" and demonstrated the structural relationships of biodiversity with landscape heterogeneity. 93.2% of bird species in organic agro-landscapes that used habitats for nesting or food searching are rare and internationally protected. Bird biodiversity is higher in FSB, which provide nesting places. The gradient of synanthropization of nesting birds increases from lower to higher: 0.2 in the experimental fields, 0.8 in the FSBs, and 0.9 – gardens.

Further research on trophic and topical relationships, structural and functional organisation of agrolandscapes, the impact of organic farming and landscape management practices, and the development of incentive systems for farmers and large-scale agricultural producers will provide valuable information and effective mechanisms for biodiversity conservation in the context of agricultural intensification. Results on existing environmental risks and ways to mitigate them in organic farming can be used for systemic analyses of biodiversity structure in agro-landscapes: fields, their margins, forest shelterbelts, etc. To comply with integrated management practices in organic farming, it is effective to use birds for pest control in fields. To attract and increase their species and ecological diversity, it is advisable to establish integrated tree and shrub plantations that provide biodiversity besides improving landscape properties and protecting fields. This helps to increase the quantity and quality of ecosystem services: crop pest control, crop pollination, conservation of food chains and biodiversity.

Acknowledgements

The authors are thankful for the Czech government support provided by the Ministry of Foreign Affairs of the Czech Republic, which allowed this scientific cooperation to start within the project "AgriSciences Platform for Scientific Enhancement of HEIs in Ukraine". There was no specific funding for this research. This research was finished with support from the Research Institute for Sustainability – Helmholtz Centre Potsdam, Germany and the Alexander von Humboldt Foundation 2024-2026.

References

Bailon A.G., Mendoza F.L., Solis L., Velasquez J., Montes K., PerlaGutierrez D.R., Kondo T. & Chirinos D.T., 2022, Endemic and invasive Coccinellidae associated with maize (*Zea* *mays* L.) fields, in Manabi province, Ecuador. Folia Oecologica 49(1): 35–41. Doi: 10.2478/foecol-2022-0004

Bennewicz J. & Barczak T., 2020, Ground beetles (Carabidae) of field margin habitats. Biologia 75: 1631–1641. Doi: https://doi.org/10.2478/s11756-020-00424-y

Bibby C., Burgess N., Hill D. & Mustoe S., 2000, Bird census techniques, 2nd ed. Academic Press, London, 303 p.

Blinkova O. & Shupova T., 2018, Bird communities and vegetation composition in natural and semi-natural forests of megalopolis: correlations and comparisons of diversity indices (Kyiv city, Ukraine). Ekologia (Bratislava), 37(3): 259–288. Doi: https://doi.org/10.2478/eko-2018-0021

Blinkova O., Shupova T. & Raichuk L., 2020, Syn-Ecological Connections and Comparison of A-Diversity Indices of Plant and Bird Communities on Cultivated Coenosises. Journal of Landscape Ecology 13(2): 62–78. Doi: https://doi.org/10.2478/jlecol-2020-0010

Camprodon J. & Brotons L., 2006, Effects of undergrowth clearing on the bird communities of the Northwestern Mediterranean Coppice Holm oak forests. Forest Ecology and Management 221: 72–82. https://doi.org/10.1016/j.foreco.2005.10.044

Chaplygina A., 2009, Patterns of nest location of thrushes of the genus Turdus in transformed landscapes of North-East Ukraine. Berkut 18(1-2): 135–142.

Chaplygina A., 2015, Ecofaunistic analysis and breeding success of dendrophilous birds on transformed landscapes of North-East Ukraine. Studia Biologica 9(2): 133–146. Doi: https://doi.org/10.30970/sbi.0902.410

Nehaniv C.L. & Rhodes J.L., 2000, The Evolution and Understanding of Hierarchical Complexity in Biology from an Algebraic Perspective. Artif. Life 6(1): 45–67. Doi: https://doi.org/10.1162/106454600568311

Felton A., Hedwall P.O., Lindbladh M., Nyberg T., Felton A.M., Holmström E., Wallin I., Löf M. & Brunet J., 2016, The biodiversity contribution of wood plantations: Contrasting the bird communities of Sweden's protected and production oak forests. Forest Ecology and Management 365(1): 51–60. Doi: http://dx.doi.org/10.1016/j.foreco.2016.01.030

Frei B., Bennett E. & Kerr J., 2018, Cropland patchiness strongest agricultural predictor of bird diversity for multiple guilds in landscapes of Ontario, Canada. Regional Environmental Change 18: 2105–2115. Doi: https://doi.org/10.1007/s10113-018-1343-5

Graviola G.R., Ribeiro M.C. & Pena J.C., 2022, Reconciling humans and birds when designing ecological corridors and parks within urban landscapes. Ambio 51: 253–268. Doi: https://doi.org/10.1007/s13280-021-01551-9

International Code of Zoological Nomenclature, (Internet), available from: https://www.iczn.org/the-code/the-code-online/

Johannesdottir L., Alves J.A., Gill J.A. & Gunnarsson T.G., 2017, Use of agricultural land by breeding waders in low-intensity farming landscapes. Animal Conservation 21(4): 273–362. Doi: https://doi.org/10.1111/acv.12390

Klausnitzer B., 1990, Ecology of urban fauna. Moscow, Russia, 248 p.

Kross S., Kelsey T., Mccoll C. & Townsend J., 2016, Field-scale habitat complexity enhances avian conservation and avian-mediated pest-control services in an intensive agricultural crop. Agriculture, Ecosystems & Environment 225: 140–149. Doi: 10.1016/j.agee.2016.03.043

Kuzmenko T.M., 2018, Ornithofauna of open agrilandscapes of the forest and forest-steppe nature zones of Left-Banked Ukraine. Ph.D. thesis, I.I. Schmalhausen Institute of Zoology of NAS of Ukraine, Kyiv.

Kuzmenko T.M., Kuzmenko Yu.V. & Gavris G.G., 2011, Avifauna of cereals fields of regions East Polissia and Forest-steppe Zone of Ukraine (seasons of 2008–2011). Scientific Bulletin of the Uzhgorod University. Series Biology 31: 97–105.

Langraf V., Petrovičová K., Krumpálová Z., Svoradová A. & Schlarmannová J., 2021, Dispersion of the epigeic fauna groups in the agricultural landscape. Folia Oecologica 48(2): 147–155. Doi: 10.2478/foecol-2021-0015.iz

Lavrov V., Miroshnyk N., Grabovska T. & Shupova T., 2021, Forest shelter belts in organic agricultural landscape: structure of biodiversity and their ecological role. Folia Forestalia Polonica, Series A – Forestry 63(1): 48–64. Doi: https://doi.org/10.2478/ffp-2021-0005

Magurran A., 2004, Measuring Biological Diversity, 2nd ed. Blackwell Press, 193 p.

Manton M., Angelstam P. & Naumov V., 2019, Effects of Land Use Intensification on Avian Predator Assemblages: A Comparison of Landscapes with Different Histories in Northern Europe. Diversity 11(5), 70. Doi: https://doi.org/10.3390/d11050070

Ondine F.-C., Jean C. & Romain J., 2009, Effects of organic and soil conservation management on specialist bird species. Agriculture, Ecosystems & Environment, 129(1–3): 140–143. Doi: https://doi.org/10.1016/j.agee.2008.08.004

Perennes M., Diekötter T., Hoffmann H., Martin E.A., Schröder B. & Burkhard B., 2023, Modelling potential natural pest control ecosystem services provided by arthropods in agricultural landscapes. Agriculture, Ecosystems & Environment, 342, 108250. Doi: https://doi.org/10.1016/j.agee.2022.108250

Pokoziy Y.T., Pisarenko V.M. & Dovgan S.V., 2010, Monitoring of crop pests: a textbook (eds.: Pokoziy Y.T.). Kyiv, Ukraine, 223 p.

Power E.F., Jackson Z. & Stout J.C., 2016, Organic farming and landscape factors affect abundance and richness of hoverflies (*Diptera*, *Syrphidae*) in grasslands. Insect Conservation and Diversity 9(3): 244–253. Doi: https://doi.org/10.1111/icad.12163

Pringle S., Chiweshe N., Steward P.R., Mundy P.J. & Dallimer M., 2019, Rapid redistribution of agricultural land alters avian richness, abundance, and functional diversity. Ecology and Evolution 9(21): 12259–12271. Doi: https://doi.org/10.1002/ece3.5713

Putchkov A.V., Brygadyrenko V.V. & Nikolenko N.Y. 2020, Ecological-faunistic analysis of ground beetles and tiger beetles (*Coleoptera: Carabidae, Cicindelidae*) of metropolises of Ukraine. Biosystems Diversity 28(2), 163–174. Doi:10.15421/012022

Shaffer J.A. & DeLong J.P., 2019, The effects of management practices on grassland birds – An introduction to North American grasslands and the practices used to manage grasslands and grassland birds, [in:] Johnson D.H., Lawrence D., Shaffer A.J. & DeLong J.P. (eds.). The effects of management practices on grassland birds. U.S. Geological Survey Professional Paper, 1842, 1–63. Doi: https://doi.org/10.3133/pp1842A

Singh R., Tiwari A.K., Kumar S. & Singh G.S., 2024, Avifaunal Diversity in Managed Urban Ecosystem: A Case Study of Banaras Hindu University, Varanasi. Ecological Questions 35(3), 1–25. Doi: 10.12775/EQ.2024.038

Smith H.G., Dänhardt J., Lindström Å. & Rundlöf M., 2010, Consequences of organic farming and landscape heterogeneity for species richness and abundance of farmland birds. Oecologia 162: 1071–1079. Doi: https://doi.org/10.1007/s00442-010-1588-2

Söderström B., Svensson B., Vessby K. & Glimskär A., 2001, Plants, insects and birds in semi-natural pastures in relation to local habitat and landscape factors. Biodiversity and Conservation 10: 1839–1863. Doi: https://doi.org/10.1023/A:1013153427422

Tarasov V.V., 2012, Flora of the Dnepropetrovsk and Zaporozhye regions. Vascular plants with their biology-ecological characteristic. Dnepropetrovsk, Ukraine, 296 p. (in Ukrainian). https://www.zoology.dp.ua/wp-content/downloads/KEDU/Tarasov.pdf

Teofilova T., 2022, Ground beetles in Romanian oilseed rape fields and adjacent grasslands (*Coleoptera: Carabidae*). Folia Oecologica 49(2): 148–158. Doi: 10.2478/foecol-2022-0017

Tribel S.O., Retman S.V., Borzyh O.I. & Strigun O.O., 2012, Strategic crops: monograph. Kiev, Ukraine, 368 p.

Vahaliuk L.V., Minyaylo A.A. & Chaika V.M., 2016, Diversity and trophic relationships of entomofauna of agro-landscapes of the Forest-Steppe of Ukraine (in Ukrainian). Biology, Biotechnology, Ecology, 234: 78–89. Doi: http://nbuv.gov.ua/UJRN/nvnau_biol_2016_234_12

Vickery J. & Arlettaz R., 2012, The importance of habitat heterogeneity at multiple scales for birds in European agricultural landscapes, [in:] Fuller R.J. (ed.), Birds and Habitat – Relationships in Changing Landscapes. Cambridge, 177–204. Doi: https://doi.org/10.1017/CBO9781139021654.009

Wesemeyer M., Kamp J., Schmitz T., Müller D. & Lakes T., 2023, Multi-objective spatial optimization to balance trade-offs between farmland bird diversity and potential agricultural net returns. Agriculture, Ecosystems & Environment 345, 108316. Doi: https://doi.org/10.1016/j.agee.2022.108316

WFO, 2025, World Flora Online. Published on the Internet; http://www.worldfloraonline.org. Accessed on: 13 May 2025.