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**ORIGINAL ARTICLE**

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# Forest shelter belts in organic agricultural landscape: structure of biodiversity and their ecological role

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## Abstract

The aim of this article is to assess the structure of biodiversity of field protective forest shelter belts to determine the directions of increasing their reclamation and conservation potential in the organic agricultural landscape. Methods of comparative ecology (synecological approach, assessment of α-diversity), forestry, geobotany, ornithology and statistical analysis are used. Changes in species diversity of plants and birds in forest shelter belts around organic fields are characterized. It is established that plantations with developed undergrowth and understorey are transformed due to the loss of up to 43.5% of trees, liquefaction of the edificatory tier. Transformer species with a wide phytocenotic range predominate in the tree stands. The grass tier is dominated by ruderants (36.5%) and adventive species (24.5%). The share (60%) of species with a mixed life strategy indicates changes in moisture conditions and soil trophism. A 2.4% of shade-loving plants and the presence of 14.7% nitrophils indicate an imbalance in the structure of forest shelter belts. Depletion of species composition, ecological and trophic structure of bird groups testify to the decrease in the capacity of forest shelter belts and their statio diversity, reduction of protective, environment-creating functions and other ecosystem services. In the three-tiered dense forest shelter belts with developed undergrowth and understorey, 10–27 species of birds nest. In general, avifauna is represented by 2 ecological groups (93.1% dendrophiles, 6.9% sclerophiles), divided into 5 types of nesting strategy (with a predominance of hollow-nests 37.0–53.3%), and 5 types of feeding (with a predominance of entomophagous 70.4–90.0%). Twenty-nine species have been identified on nesting, 27 of which are subject to protection at the level of international agreements. There are no adventive species, the index of synanthropization of avifauna is high – 0.85–1.0. For organic technologies to increase the potential of biological protection of fields from entomological pests by attracting insectivorous birds is relevant.

## Key words

avifauna, community, ecosystem, grass cover, phytoindication, tree vegetation

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## Introduction

Global intensification of agriculture, population growth, industrialization and climate change are the main causes of biodiversity's and its ecosystem functions' degradation (Udawatta et al. 2019). The structure of biodiversity, especially forest cover, is a rather informative indicator of the degree of anthropogenic pressure on the natural environment. In regions with arable lands, such as the Right-Bank Forest-Steppe of Ukraine, little natural vegetation has been preserved for a long period of agricultural production. As a result of economic activity and the laying of transport networks of various types, the habitats of animals of forest and other ecosystems are fragmented and divided by anthropogenic landscapes. In small forest regions, complexes of protective plantations, first of all field protective forest shelter belts (FSB), become almost the only corridors of connection of natural ecosystems fragments, divided biotopes, remnants of natural frame of territories. Depending on the species, size, condition and other forest-assessment indicators, the forest environment necessary for the conservation and migration of wild animals is to some extent maintained in FSB (Furdychko and Lavrov 2009; Furdychko and Stadnyk 2012; Lavrov et al. 2016). However, in modern conditions of urbanization intensification, economic development of landscapes, changes in land use due to land reform, development of transport infrastructure, as well as improper care of the FSB system, their illegal cutting, anthropogenic pollution in Ukraine, their fragmentation increases, their productivity and sustainability, the period of existence reduces, which causes a significant decrease in the ability of forest belts to perform ecosystem functions (Furdychko and Lavrov 2009; Furdychko and Stadnyk 2012; Lavrov et al. 2016). Similar negative effects of human activities on protective plantations have been found in other countries (Livesley et al. 2016; Huse et al. 2016). The spectrum of human activity influences well reflects the change of different characteristics of the vegetation flora structure: taxonomic, chorological, biomorphological, coenotic and ecological. Due to the significant diversity of sensitive species with different biological and ecological characteristics, the grass layer is able to quickly, objectively and integratedly reflect the nature of changes, allows establishing their causes, synecological effect of their interaction (combined effect of factors) and predict future changes (Ramenskij 1971; Tsyganov 1983; Mirkin et al. 2001; Lavrov 2003; Zhukova et al. 2010; Voron et al. 2011; Didukh 2012; Lavrov et al. 2019). Therefore, for phytoindication of FSB violation, it is expedient to study the systematic, biomorphological and ecological characteristics of the grass tier of forest belts. Of particular concern is the possibility of the loss of rare plants and animals, endangered species in the agrolandscapes. It is expected that to some extent the conservation of biodiversity can contribute to the completion of the ecological network, in which FSB plays the role of ecological corridors, as well as organic agricultural production, which in recent years is actively developing (Lavrov 2003; Furdychko and Lavrov 2009; Lavrov et al. 2016; Grabovska and Lavrov 2019). The aim is to assess the structure of biodiversity of field protective forest shelter belts to determine the directions of increasing their reclamation and conservation potential in the organic agricultural landscape.

## Material and methods

The study was conducted on agricultural lands of Institute of Agroecology and Environmental Management of NAAS of Ukraine (Skvyra, Kyiv region; GPS coordinates 9°41'49.6»N 29°39'46.9»E). This is the only certified demonstration site in Ukraine created within the project 'Development of the organic market in Ukraine' (according to FIBL agreement, since 2013). It was taken as a typical agrolandscape for the Forest-Steppe zone. Organic crops along the perimeter of the field with an area of 40 hectares are protected by four forest shelter belts of different assessment and sanitary characteristics (Fig. 1; Tab. 1). According to the physical and geographical zoning of Ukraine, the study area belongs to the North-Eastern Dnieper Upland and Kyiv Upland Regions of the Podilsk-Prydniprovsky Forest-Steppe Region. The study area is of national importance in the structure of the national ecological network.

### Methods of vegetation research

FSB was investigated in June 2019 by the route method around organic fields (Fig. 1). The spatial structure (construction) of forest belts, their species composition and sanitary condition of the stand were studied by forestry methods (Anuchin 1982; Sanitary rules…, 1995; Voron et al. 2011). The grass tier of the forest belts was studied taking into account the assessment and sanitary characteristics of the stand. On the typical areas of the forest shelter belts, trial plots (TP) with a length of 100 m (on both field edges and inside the forest strip) were laid. Continuous accounting of the species composition and the assessment of the total projective cover (TPC) of the grass tier were carried out there. The design of FSB and the degree of its degradation, the number of rows and 'free'/'empty' seats in them (plant mortality), the height and width of the forest belt, the density of canopy, the composition of the tiers of trees, shrubs and grasses phytocenosis and also a sanitary condition of an edificatory tier of tree species are determined.


**Figure 1.** Structure of the studied organic agrolandscape (demonstration site of Institute of Agroecology and Environmental Management of NAAS of Ukraine): OF – organic fields; CF – conventional fields; 1, 2, 3, 4 – forest shelter belts No. C1, C2, C3 – sections of the forest belt No. 4; $G_1$, $G_2$ – fruit gardens, $G_3$ – dendrological garden; VG – vegetable garden; AB – administrative buildings; FY – farmyard; P-32, P-18 – regional routes

The degree of stands damage formed by several species was assessed by the state index (Ic) of the first tier for mixed stands, which was calculated by Voron et al. (2011) (formula 1):

$$I_C = \frac{k_1\left(n_a + n_b \ldots + n_i\right) + \\ + k_2\left(n_a + n_b + \ldots n_i\right) + \\ + \ldots k_6\left(n_a + n_b + \ldots n_i\right)}{N} \quad (1)$$

where:

$Ic$ – the state index of the stand,

$k_1$–$k_6$ – the category of tree state (from I to VI) (Sanitary rules…, 1995),

**Table 1.** Assessment and sanitary characteristics of field protective forest shelter belts around the organic experimental fields (Institute of Agroecology and Environmental Management of NAAS of Ukraine)

| No FSB, trial plots (TP) – sections (C), placement relative to organic fields | FSB construction | Number of rows of tree species, pieces | Species composition | | FSB parameters, m | | Density of canopy* | Plantation condition | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | main tent | undergrowth and understorey | H | B | | $I_c$ | sanitary | forestry |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| FSB No 1, TP1, west side of the field | two-tier, dense | 4 | main speices – *Fraxinus excelsior* L.; accompanying – *Ulmus laevis* Pall., *Populus nigra* L., *P. laurifolia* Ledeb., *Robinia pseudoacacia* L., *F. excelsior*, *Ulmus laevis* Pall., *U. minor* Mill.; invasive – *Juglans regia* L., *Populus tremula* L., *Acer negundo* L. | UNDERGROWTH: *A. negundo*, *Acer pseudoplatanus* L., *U. minor*, *F. excelsior*, *J. regia*, *Malus domestica* Borkh.; UNDERSTOREY: *Prunus serotina* Ehrh., *Sambucus nigra* L., *Ligustrum vulgare* L. *Crataegus monogyna* JACQ., *Padus avium* Mill. | 17.4 | 20.0 | 0.58 | 2.43 | weakened | good, TPC – 38.1% |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| FSB No 2, TP2, north side of the field | three-tier, dense | 7** | main speices – *Populus nigra* L.; accompanying – *P. laurifolia, Quercus robur* L., *Fraxinus pennsylvanica* Marshall, *U. laevis*; invasive – *R. pseudoacacia*, *Cerasus avium* (L.) Moench, *J. regia*, *A. negundo* | UNDERGROWTH: *R. pseudacacia*, *Q. robur*, *C. avium*, *F. excelsior*, *A. negundo*; UNDERSTOREY: *S. nigra*, *Prunus cerasifera* Ehrh., *P. serotina*, *Padus avium* Mill., *Swida sanguinea* (L.) Opiz., *Ligustrum vulgare* L. | 24.3 | 35.0** | 0.81 | 2.28 | weakened | good, TPC – 25.6% |
| FSB No 3, TP3, east side of the field | one-tier, dense | 2 | main speices – *P. laurifolia*; accompanying – *Q. robur, F. pennsylvanica*, *F. excelsior, U. laevis*; invasive – *Q. rubra* L., *Pyrus communis* L., *J. regia, A. negundo*, *P. tremula*, *C. avium* | UNDERGROWTH: *Q. robur, F. excelsior, U. laevis, P. communis*, *J. cinerea* L., *M. domestica*, *C. avium*, *A negundo*; UNDERSTOREY: *Sorbus aucuparia* L., *P. serotina*, *S. nigra, S. sanguinea*, *Cerasus vulgaris* Mill., *L. vulgare*, *Rosa canina* L. | 22.6 | 16.0 | 0.72 | 2.23 | weakened | good, TPC – 31.2% |
| FSB No 4, TP4-C1 south side of the field | dense | 3 | main speices – *U. minor*; accompanying – *F. excelsior*; invasive – *R. pseudoacacia*, *A. negundo*, *J. regia* | UNDERGROWTH: *J. regia*, *A. negundo*, *C. avium*, *M. domestica*; UNDERSTOREY: *P. serotina*, *Salix caprea* L., *S. sanguinea* (L.) Opiz., *S. nigra*, *C. monogyna* | 14.2 | 12.0 | 0.62 | 1.48 | healthy | good, TPC – 17.6% |
| FSB No 4, TP4-C2 south side of the field | wind-per-meable, there are gaps in the forest belt up to 20 m wide | 1 | main speices – *U. laevis*; invasive – *J. regia*, *A. negundo*, *R. pseudoacacia*, *S. caprea* | UNDERGROWTH: *M. domestica*, *J. regia*, *A. negundo*, *P. communis*, *C. monogyna*; UNDERSTOREY: *P. serotina*, *S. nigra*, *L. vulgare*, *S. caprea*, *S. sanguinea* | 12.5 | 4.0 | 0.51 | 1.42 | healthy | satisfactory, the stand is liquefied, TPC – 42.8% |
| FSB No 4, TP4-C3 south side of the field | semi-permeable | 2 | main speices – *F. excelsior*; accompanying – *Acer pseudoplatanus* L., *U. minor*; invasive – *R. pseudoacacia*, *J. regia*, *A. negundo*, *S. caprea* | UNDERGROWTH: *A. negundo*, *P. communis*, *J. regia*, *C. avium*, *M. domestica*; UNDERSTOREY: *P. serotina*, *S. caprea*, *C. monogyna*, *P. avium*, *Rubus caesius* L. | 13.4 | 8.0 | 0.55 | 1.37 | healthy | satisfactory, the stand is liquefied, TPC – 26.4% |

**Note**: C – sections of TP are distinguished by the difference in structure (according to the degree of degradation) of the forest shelter belt No 4; * – for one-row FSB – density in a row; ** – TP2 had a projective width of 50.0 m (10 rows of trees, row spacing – 5 m, between rows – shade-tolerant shrubs (*Sambucus nigra* L., *Swida sanguinea* (L.) Opiz., *Ligustrum vulgare* L.). In 2018, reforestation of the field belt 15 m wide (three rows of trees) was carried out, so FSB became 7-row, width – 35 m. As a result of felling there is an active restoration of trees from stumps (stump growth), free areas are occupied by a dense cover of grass in the form of biogroups. H is the height of FSB, B is the width of FSB, Ic is the index of the stand sanitary condition, TPC is the total projective cover of the grass layer in the FSB (%).

$n_a$, $n_b$ ... $n_i$ – the number of different tree species in one state category, individuals,

N – the total number of evaluated trees in the trial plot, individuals.

Stands with an index of 1.00–1.50 were considered healthy (no damage); weakened – 1.51–2.50 (weak damage); severely weakened – 2.51–3.50 (average damage); wilting – 3.51–4.50 (severe damage); dead – 4.51–6.00 (the damage is very strong) (Voron et al. 2011).

Vegetation was studied by methods of Mirkin et al. (2001). We identified the Latin names of vegetation taxons by Mosyakin and Fedoronchuk (1999). The biomorphological structure of vegetation is given by Serebrjakov (1962). Ecomorphic analysis was performed according to Tarasov (2012) with additions according to 'Ecoflora of Ukraine' (Didukh 2004). Family names are given according to the system of Takhtajan (2009).

To synecologically determine the degree of anthropogenic transformation of FSB (except *Ic* of stand), the effects of changes in the ecosystem environment on the grass tier were also assessed by the grassland therophyte/geophyte ratio and the TG index (ITG) (formula 2).

$$ITG = (G - T) / (G + T) \quad (2)$$

where:

*T*, *G* are the shares of therophytes and geophytes in the species composition of grasses (Goncharenko 2017). The value of TG-index for natural cenoses is positive, because the ratio of therophytes/geophytes is greater than 1, and, conversely, for synanthropic cenoses TG-index is negative and has a range of values [–1; 1].

Types of ecological strategies of plants were described according to the scheme of Ramensky – Grime (Grime 1977). Plant life-forms are given by Raunkiaer (Raunkiaer 1936; Mirkin et al. 2001). Projective cover of grass species was evaluated on the Brown-Blanc scale (Mirkin et al. 2001), where 1 point is up to 5%, 2 – 5–25%, 3 – 25–50%, 4 – 50–75% and 5 – 75–100%. The index of vegetation adventization (separately for trees and grass tiers) was established as a share of alien species from the total number of species in a certain test plot. Changes in ecological conditions were detected by the structure of the grass tier, using scales (Tsyganov, 1983). The effect of changes on plants in the regime of leading environmental factors – climatic (thermo- (Tm), ombro- (Om) and cryo-regime (Cr), continentality (Kn)); edaphic (generalized salt regime (Tr), nitrogen (Nt) and acid (Rc) regimes, soil moisture (Hd) and its changes (fH)), as well as shading-light regime (Lc) was evaluated. The values of the regimes of ecological factors were calculated as arithmetic averages. The ecological valence of grass species was determined by Jukova et al. (2010). Their tolerance index (*It*) was calculated as the sum of ecological valencies divided by the sum of the scales. Stenobionts (SB) – species in which $It < 0.34$, hemistenobionts (HSB) – $It < 0.46$, mesobionts (MB) – $It < 0.56$, hemieurybionts (HEB) – $It < 0.67$ and eurybionts (EB) – $It > 0.67$.

#### Studies of avifauna

Were conducted from 6.00 to 12.00 am by the common method of counting birds on routes (Järvinen and Väisänen 1975; Bibby 2000). The length of the observation line was 2300 m, the survey covered the entire width of the forest strip (4–35 m), and the total survey area was 6.6 ha. The audio definition of birds' voices (mp3) was used for the acoustic identification of species. The average nesting density of birds, its standard deviation and variance were calculated.

The list of bird species is provided in accordance with the 'International Code of the Zoological Nomenclature' (International Code … 1999). Analysis of avifauna by ecological groups and trophic specialization was carried out in accordance with the method of Belik (Belik 2006, 2009). We compared the share of ecological groups of birds that are indicative for the assessment of groups, namely: the number of bird species that are subject to protection in accordance with the lists of international conventions and the Red Book of Ukraine; ecological guilds of the group, depending on the microstations they choose to build a nest (Snow and Perrins 1998; Camprodon and Brotons 2006; Shupova 2017; Blinkova and Shupova 2017; Blinkova and Shupova 2018). We evaluated the index of synanthropization of nesting birds' communities, according to formula 3, proposed by Jedryczkowski (formula 3):

$$Ws = L_s/Lo, \quad (3)$$

where:

*Ls* – the number of synanthropic species, *Lo* – the total number of species (Klausnitzer 1990).

Statistical data processing was performed using a computer program Microsoft Excel by Dospekhov (2012).

## Results

The organic fields are surrounded on the perimeter by the field protective forest shelter belts of weakened state (Tab. 1): FSB No 1 (from the west) – 4-row dense two-tier forest shelter belt with a width (B) of 20.0 m and a height (H) of 17.4 m. In the first tier, the main species is *Fraxinus excelsior* L., *Ic* = 1.37, with an admixture of *Populus nigra* L. (*Ic* = 1.42), *Ulmus laevis* Pall. etc.; in the second tier – *Populus laurifolia* Ledeb., *F. excelsior*, *U. laevis*, *U. minor* Mill. and severely weakened (*Ic* = 3.47) *Robinia pseudoacacia* L. This reduces the general condition of the forest belt. *Juglans regia* L., *Populus tremula* L. and *Acer negundo* L. penetrated into the stand. *A. negundo* (17.4 m high) in the zone of the edges (74.3% of their territory) has formed a wind-impermeable entire edge. Slight canopy density (0.58) contributes to the development of undergrowth and understorey and increase the TPC to 38.1%. Ten species of birds in the amount of 1–3 pairs of each species nest in the forest shelter belt, with an average density of 1.0±0.18 pairs/ha, density dispersion 0.55, synanthropization index of community is 1. *Parus major* L., *Sitta europaea* L., i.e. birds that nest in hollows are dominated by the number. The community is represented by 1 ecological group – dendrophiles, which use 4 types of nesting strategy and are divided into 2 feeding groups.

FSB No 2 (from the north) is 7-row most dense three-tier forest belt (B = 35.0 m; H = 24.3 m) with developed undergrowth and understorey. In the first tier, the main species is *P. nigra* (diameter 86 cm, height 23.8 m, *Ic* = 2.28) with an admixture of *P. laurifolia*. The second tier is formed by *Quercus robur* L. (*Ic* = 1.34), *Fraxinus pennsylvanica* Marshall, *Juglans cinerea* L., *U. laevis*, *U. minor*, *A. negundo* (H = 6.3–18.6 m) has formed a dense edge. However, it is short-lived and quickly loses viability (*Ic* = 3.16). In the third tier there are many species of different ages. Undergrowth is suppressed due to the high canopy dense (0.81). Understorey is developed mainly on the edge of the forest up to 12 m. Signs of anthropogenic impact: sanitation cutting of shelter belt 15 m wide which are close to the field, remains of burning cut residues – 1.2% of its area, litter – 25.6% of the area of FSB, tree mortality – 33.2%, TPC of grass tier in the spaces of the tent – 45.2%. Twenty-seven species of birds in the number of 1–10 pairs of each species nest in the forest shelter belt, with an average density of 0.9±0.13 pairs/ha, a dispersion density of 0.70, and a community synanthropization index of 0.85. *Parus major* L. and *Fringilla coelebs* L. dominate by the number, i.e. hollow-nesting and crown-nesting birds. The community is represented by two ecological groups (dendrophiles, sclerophiles), which use 5 types of nesting strategy, and are divided into 5 feeding groups.

FSB No. 3 (from the east) is 2-row one-tier dense forest shelter belt, 16.0 m wide and 22.6 m high. The main species is *P. laurifolia*, accompanying are *Q. robur*, *F. pennsylvanica*, *F. excelsior*, *U. laevis* and others. The forest belt has two tiers of the main stand. The third tier of young trees and shrubs is well developed in the degraded areas (undergrowth with an average height of 7.5 m and understory of 0.7–3.8 m). There are mechanical damages on the tree trunks, hollows have been formed in some places. Mortality of the main species is 26.8%. TPC of grass tier in the forest belt is 31.2%. Fifteen species of birds nest in the number of 1–3 pairs of each species, with an average density of 2.9±0.34 pairs/ha, a dispersion density of 1.31 and a community synanthropization index is 0.93. High dispersion indicates a significant anthropogenic impact on the birds living. *Parus major* L., *Erithacus rubecula* L., which build closed nests, and *Turdus merula* L., which builds open nests in tree canopies dominate. The community is represented by two ecological groups (dendrophiles, sclerophiles), which use 4 types of nesting strategy, and are divided into 2 feeding groups.

FSB No. 4 (from the south) is 1-, 2- and 3-row remnants of degraded forest shelter belt, which we divided, respectively, into three sections (C1, C2, C3). They differ in width (B = 4.0–12.0 m) and height (H = 12.5–14.2 m) of the stand; by density, which means – by field protective ability – wind-permeable, semi-permeable and dense. Now these fragments of FSB have different main species: *U. laevis* (C1), *F. excelsior* (C2), *U. minor* (C3). They are formed by different numbers of accompanying and invasive species of trees and shrubs. Due to the significant liquefaction of the wooden tent (0.62; 0.51; 0.55), 42.8%, 25.2% and 17.6% of the territory of these forest belt fragments were captured by the grassland, respectively. Three species of birds, 1 pair of each species nest here. All species are optional synanthropes. With this species and quantitative composition, the community cannot be distinguished. All 3 species are dendrophiles, representing 3 nesting strategies and 2 feeding groups.

As an integral indicator of the species stability degree in the phytocenosis, we estimated the type of vegetative mobility of woody plants (type of vegetative reproduction). It was found that in all FSB, vegetatively sedentary and immobile species predominate (Tab. 2). That is, the conditions of the sub-canopy space do not contribute to the reproduction of vegetatively mobile species. Biological and ecological adaptations of species are integrated into the strategy of their behaviour. The life strategy (type of behaviour) of a plant is the most important characteristic of a species, which reflects its reaction to abiotic and biotic environmental conditions.

**Table 2.** The structure of bio- and ecomorphs of FSB dendroflora

| Factors | Life form | Share of species, % |
|---|---|---|
| Biomorphs by IG Serebryakov (1962) | trees | 77.4 |
| | shrubs | 21.3 |
| | lianas | 1.3 |
| Type of vegetative mobility | vegetatively sedentary | 38.6 |
| | vegetatively immobile | 32.3 |
| | vegetatively mobile | 29.1 |
| Heliomorphs | heliophytes | 64.5 |
| | scioheliophytes | 6.5 |
| | heliosciophytes | 29.0 |
| Hydromorphs | xeromesophytes | 9.7 |
| | mesohygrophytes | 3.2 |
| | mesoxerophytes | 12.9 |
| | mesophytes | 74.2 |
| Trophomorphs | megatrophs | 12.9 |
| | mesotrophs | 80.6 |
| | oligotrophs | 6.5 |
| | of which nitrophils | 16.1 |

The studied forest belts are dominated by tree species of mixed ecological strategies, in particular violents – patients (CS, 58.3%). These are resistant to stress, lack of resources and competitively strong species of *P. laurifolia* Ledeb., *P. nigra* L., *P. communis* L., *U. laevis* Pall., *J. regia* L. and others. Plants with C-strategy (explerents) are second by number (20.3%, *Q. rubra* L., *S. nigra* L.), which indicates a violation of living conditions; in third place S – stress-tolerants (14.4%; *Cerasus vulgaris* Mill., *Crataegus monogyna* JACQ.). There was a small representation of the secondary strategy SR (4.7%), which is characterized by the alien species *Parthenocissus quinquefolia* (L.) Planch. Adventive species with CR strategy (combination of signs of violents and explerents) are 2.3%. These are very strong competitors, which are expansive transformers, species with long ontogenesis, coeno-populations of which cover several stages of succession (Protopopova et al. 2014), that suppress other species – *A. negundo*, *R. pseudoacacia*.

Heliomorphs are dominated by heliophytes and heliosciophytes due to liquefaction and reproduction of the species-transformer *A. negundo*, which prevents the secondary reproduction of aboriginal species of woody plants, and, accordingly, the dense of tree canopy. The water regime is dominated by mesophytes, the requirements for soil trophics – by mesotrophs. Nitrophiles make up 5–6.5% (Tab. 3).

**Table 3.** The structure of bio- and ecomorphs of FSB wood nitrophils

| Species | Biomorph | Cenomorph | Trophomorph | Hygromorph |
|---|---|---|---|---|
| *Acer negundo* L. | tree | Ru, @ | MgTr | Ms |
| *Sambucus nigra* L. | bush | Sil | MgTr | Ms |
| *Swida sanguinea* (L.) Opiz. | bush | Sil | MgTr | Ms |
| *Rubus caesius* L. | bush | Sil | MgTr | MsHg |
| *Parthenocissus quinquefolia* (L.) Planch. | liana | Sil, @ | MsTr | Ms |

Notes: Ru – ruderant; @ – adventive type; Sil – silvant; MgTr – megatroph; MsTr – mesotroph; Ms – mesophyte; MsHg – mesohygrophyte.

The studied dendroflora of FSB includes 30 species from 22 genera and 12 families. Division Pinophyta is 3.3% of species, Division Magnoliophyta – 96.7%

(Tab. 4). There were 77.4% of trees, 21.3% of shrubs and 1.3% of lianas. The most complete systematic structure of vegetation is reflected in the percentage of species from different families. But due to the significant imbalance of plantations, the systematic structure of the studied FSB is broken. In particular, the family *Rosaceae* (8 species) is in the first place, *Salicaceae* (4 species) is in the second, *Ulmaceae*, *Oleaceae*, *Fabaceae* (3 species each) are in the third and the other 7 families contain 1–2 species.

**Table 4.** Systematic structure of FSB dendroflora

| Classes and species | Number of species | Share of species (%) |
|---|---|---|
| Division *Pinophyta* | | |
| *Pinaceae* | 1 | 3.2 |
| Division *Magnoliophyta* | | |
| *Aceraceae* | 2 | 6.5 |
| *Adoxaceae* | 1 | 3.1 |
| *Betulaceae* | 1 | 3.2 |
| *Cornaceae* | 1 | 3.2 |
| *Fabaceae* | 3 | 9.7 |
| *Juglandaceae* | 2 | 6.5 |
| *Oleaceae* | 3 | 9.7 |
| *Rosaceae* | 8 | 29 |
| *Salicaceae* | 4 | 12.9 |
| *Ulmaceae* | 3 | 9.7 |
| *Vitáceae* | 1 | 3.3 |
| Total | 30 | 100 |

Quantitative indicators of dendroflora taxa of the studied FSB in general are as follows: families – 29, genera – 24, species – 29, which belong to the Division of Magnoliophyta (30 species) and the Division of Pinophyta (1 species), including adventive species – 15, nitrophilic species – 5 (16.1%). The dendroflora adventization index is 50.0%, which is due to direct human intervention (planting of introducents), to a lesser extent – self-settlement of transformer species *A. negundo*, *R. pseudacacia* (Protopopova et al. 2014) and *Juglans regia* L. Wild introducents (ergasiophytes) make up almost 30% of adventive species, of which the most common are North American species: *A. negundo*, *R. pseudoacacia*, *Q. rubra*, *P. quinquefolia* (L.) Planch.

It was found that plantations with developed undergrowth and understorey are weakened (TP1, TP2, TP3), 26.8–43.5% of trees have a liquefied edificatory tier due to the mortality (TP1) or it is too narrow 1–3-row remnants of degraded forest shelter belt (TP4-C1, C2, C3; Tab. 1). Over time, due to the deterioration of the main species, there was a partial change of dominants, the activization of development of the second tier (accompanying species) and the restructuring of the stands construction (TP2, TP3). Therefore, the dense of the canopy in the wide forest shelter belts is still high (0.72–0.81). This ensures the maintenance of appropriate forest conditions in these stands, favourable for birds, other species of biota, as well as sufficient potential to protect agricultural land from negative abiotic factors. The TPC of the grass tier is high in FSB No 4 (TP4; 17.6–42.8%) and in narrow 2–4-row forest shelter belts (TP1 – 38.1%, TP3 – 31.2%). In dense stands, the formation of grass is observed only in the gaps of the tree tent (TP2 – 25.6%).

Typically, in modern floristics, much attention is paid to the 10 leading families, which are a reflection of the basic properties of flora and are the main part of the spectrum of families. We found 102 vascular plants from 32 families and 85 genera in the grass cover of FSB. In the distribution of species between classes, *Liliopsida* accounts for 14.7%, *Magnoliopsida* – 83.3%, the total ratio of the species number *Liliopsida*: *Magnoliopsida* is 1:6. The class *Polypodiopsida* includes 2 species – *Equisetum arvense* L. and *E. fluviatile* L., plants of the class *Bryopsida* were not found. Among the 10 leading families of herbaceous plants, as in most Holarctic flora (Tarasov 2012), *Asteraceae* ranks first – 22 species or 21.6% of the total number of species. Such a high position of the family is characteristic of almost all natural flora of the globe, including and for synanthropic flora of Ukraine (Protopopova et al. 2006). *Poaceae* (15 species, 14.7%) is in the second place; *Brassicaceae* – 6 species, or 5.9%; *Fabaceae*, *Polygonaceae* each has 5 species, or 4.9%, *Caryophyllaceae* and *Lamiaceae* – 4 species each or 3.9%, 5 families contain 3 species, or 2.9%; 14 families have 1 species (1.9%), almost all of their representatives are adventives plants that are archaeophytes and/or quarantine weeds (*Portulaca oleracea* L., *Amaranthus retroflexus* L., *Asclepias syriaca* L., *Fumaria officinalis* L., *Anagallis arvensis* L. (ANGAR)), members of the families *Vitaceae* (*Vitis vinifera* L.) and

*Polygonaceae* (*Fagopyrum esculentum* Moench) – that escaped from the crop. The share of the first 7 families is 59.8% (61 species) of the total number of species. The dominance of the *Poaceae* family is characteristic of most floras of the Holarctic and typical of the flora of Ukraine. The studied FSB is characterized by the presence in the family spectrum of *Urticaceae* – sixth place and Plantaginaceae – seventh place (as well as for FSB in the Cherkasy region (Tab. 5). These families are not typical for the 10 leading families of comparable flora.

**Table 5.** Comparative spectra of leading families of different flora

| Family | The place of the family in the flora | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| *Asteraceae* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| *Poaceae* | 2 | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| *Fabaceae* | 3 | 2 | 4 | 4 | 4 | – | 3 | 3 |
| *Brassicaceae* | 9 | 5 | 2 | 6 | 3 | 3 | 5 | 4 |
| *Caryophyllaceae* | 18 | 6 | 9 | 5 | 5 | 4 | 4 | 6 |
| *Lamiaceae* | 6 | 8 | 5 | 7 | 5 | 7 | 2 | 5 |
| *Apiaceae* | 10 | 10 | 6 | 11 | 7 | 5 | 12 | 9 |
| *Cyperaceae* | 4 | 11 | – | 10 | – | – | + | 11 |
| *Rosaceae* | 8 | 4 | – | 3 | 7 | – | 11 | 7 |
| *Chenopodiaceae* | 19 | – | 7 | 18 | 8 | + | + | 12 |
| *Scorphulariaceae* | 5 | 7 | 8 | 9 | 8 | + | 4 | 10 |
| *Boraginaceae* | 16 | – | 10 | 12 | 6 | – | – | 13 |
| *Ranunculaceae* | 17 | 9 | – | 14 | 8 | + | 3 | 8 |
| *Poligonaceae* | 25 | – | – | 14 | 4 | 5 | 4 | 15 |
| *Euphorbiaceae* | 12 | – | – | 16 | 6 | 5 | + | + |
| *Convolvulaceae* | + | – | + | – | 8 | 5 | – | - |
| *Geraniaceae* | + | + | + | – | 6 | 5 | – | - |
| *Urticaceae* | – | + | – | + | 6 | 6 | + | - |
| *Violaceae* | – | – | – | + | – | 6 | + | + |
| *Plantaginaceae* | – | – | – | – | 7 | 7 | + | 14 |
| *Papaveraceae* | – | – | – | – | 7 | – | – | – |
| *Oxalidaceae* | – | – | – | – | 7 | – | – | – |
| *Equisetaceae* | – | – | – | – | 7 | – | – | – |

Notes: Flora: 1 – Holarctic (Hohrjakov 2000); 2 – Ukraine (Didukh 2004); 3 – synanthropic Ukraine (Protopopova et al. 2006); 4 – Northern Bukovina (Termena et al. 1992); 5 – FSB studied by us; 6 – FSB in the area of Cherkasy (Lavrov et al. 2019); 7 – valleys of the Tyasmin River (Lavrov et al. 2016); 8 – Left-Bank Forest-Steppe of Ukraine (regional landscape park 'Gadyatsky' (Poltava region, Ukraine)) (Khannanova 2015); '–' – are below the 20th place; '+' – are below the 15th place.

The families *Poligonaceae* and *Euphorbiaceae* occupy the 4th and 6th places, respectively, while in other floras they are not included even in the first 20 families. In the genus spectrum *Poa* L. (4 species), *Urtica* L., *Trifolium* L., *Euphorbia* L. (3 species each), *Cannabis* L., *Equisetum* L., *Geranium* L., *Plantágo* L. (2 species each) have the highest species diversity. All other genera are represented by 1 species.

According to the ratio of families depending on the degree of transformation (*Asteraceae* + *Brassicaceae*) *Rosaceae* is equal to 14 and is close to the herbaceous-pioneer stage of development characteristic of settlements (Didukh 2012). The ratio (phanerophytes + hamephytes)/therophytes is equal to 0.10 and corresponds to the weed-pioneer stage of cenoses development during succession (or gardens) (Didukh 2012).

Taking into account the imbalance of the systematic structure of the studied plantations, it is necessary to analyze the ratios of biomorphs of herbaceous plants, which indicates the peculiarities of the vegetation adaptation of the studied area to anthropogenic changes (Tab. 6). We found that there is almost the same number of annual species compared to perennial species. Plants species without rosettes are most common in the studied FSB. The structure of underground shoots is dominated by species without formations, then – long-rhizomed, plants with a taproot system predominate. The type of vegetative mobility in FSB is dominated by vegetatively immobile species (55–57%; *Arctium lappa* L., *Artemisia absinthium* L., *Cannabis ruderalis* Juseh., *Urtica urens* L., *Poa annua* L. etc.), which indicates the adaptation of species to the formed ecological conditions: special microclimate under the tent of plantations and the neighbourhood of agricultural lands, gardens, roads and other areas (Fig. 1). Plants 'migrate' from them under the tent of FSB, and to a lesser extent – the seeds of these plants come from other FSB. Analysis by climamorphs showed that hemicryptophytes predominate in all FSB, which is characteristic of the Holarctic. It is worth noting a significant number of geophytes – 15.5%. In relation to light, heliophytes predominate, followed by shade-tolerant species (25%), ruderants are in the largest number (49–54%) in all studied FSB, and silvants are almost 2 times less than ruderants. The advent component of the flora occupies 24.5% (32 species), which indicates a significant secondary anthropogenic transformation of ecotopes. Under the tent of plantations there are malignant weeds (*Sonchus arvensis* L., *Setaria pumila* (Poir.) Roem. & Schult., *Melandrium album* (Mill.) Garcke, *Portulaca oleracea* L., *Stellaria media* (L.) Vill., *Thlaspi arvense* L.), that escaped from the crop (*Raphanus sativus* L., *Cannabis sativa* L., *Fagopyrum esculentum* Moench) and invasive adventive transformer species (*Ambrosia artemisiifolia* L., *Impatiens parviflora* DC., *Conyza canadensis* (L.) Cronquist, *Cyclachaena xanthiifolia* (Nutt.) Fresen., *Asclepias syriaca* L., *Reynoutria japonica* Houtt.). In particular, *Reynoutria japonica* Houtt. included in the list of the most dangerous invasive species according to IUCN. Most species of the adventive fraction are united by the family *Asteraceae* – 7 species (or 6.9% of the total number of adventives). They are dominated by North American invasive species – *A. artemisifolia*, *Galinsoga parviflora* Cav., *S. annua*, *Cannabis ruderalis* Juseh. etc. However, the adventive coefficient – an indicator of ecosystem resistance to phytoinvasions (Burda and Koniakin 2019) of the studied plantations does not exceed the data on coenoses of the forest-steppe Dnieper floodplain (29–33%) (Protopopova et al. 2006). *ITG* is negative, which indicates the transformed living conditions of grass species (Table 6). It is worth noting the presence of plants (10% of the total number of grass tier species we found), that are typical for growing along rivers and wetlands (*Xanthium strumarium* L., *Bromus hordeaceus* L., *Epilobium adenocaulon* Hausskn., *Poa trivialis* L., *Amaranthus retroflexus* L., *Armoracia rusticana* P.G. Gaertn., B. Mey. & Scherb., *Equisetum arvense* L., *E. fluviatile* L., *Persicaria maculosa* S.F. Gray, *Geum rivale* L.). This indicates the wetness of the soil conditions under the FSB tent compared to massive forests (where mesophytes and xeromesophytes predominate).

Thus, the analysis of the biomorphological spectrum of the grass cover of the studied FSB indicates a high degree of species diversity. Significant participation in its structure is taken by ruderants, in particular adventive species, disturbed distribution by coenomorphs. This indicates a significant flow of seeds of cultivated plants (*Raphanus sativus* L., *Cannabis sativa* L., *Fagopyrum esculentum* Moench) and weeds (e.g., *Ambrosia artemisiifolia L., Cirsium oleraceum* (L.) Scop., *Conyza canadensis* (L.) Cronquist, *Cyclachaena xanthiifolia* (Nutt.) Fresen., *Xanthium strumarium* L., *Setaria pumila* (Poir.) Roem. & Schult., *Amaranthus retroflexus* L., *Melandrium album* (Mill.) Garcke, *Elytrigia repens* (L.) Nevski) from agricultural lands, less – silvants (*Chelidonium majus* L., *Cynoglossum officinale* L., *Epilobium adenocaulon* Hausskn., *Geranium rob-*

**Table 6.** The structure of life forms of the FSB grass tier

| Signs of life forms | Life forms | Number, individuals | Share of all herbaceous plants on TP,% |
|---|---|---|---|
| Life cycle duration | Annuals | 40 | 50.6 |
| | Perennials | 39 | 49.4 |
| The structure of aboveground shoots | Creeping | 5 | 5.8 |
| | Rosette | 16 | 20.1 |
| | Without rosette | 54 | 70.7 |
| | Turf | 3 | 2.3 |
| | Creepers (climbing) | 1 | 1.1 |
| The structure of underground shoots | Long-rhizome | 20 | 24.1 |
| | Short-rhizome | 16 | 19.3 |
| | Without formations | 40 | 48.2 |
| | Bunch-root | 7 | 8.4 |
| Type of root system | Taproot | 65 | 63.7 |
| | Fibrous root | 37 | 36.3 |
| Type of vegetative mobility | Vegetatively mobile | 20 | 26.3 |
| | Vegetatively sedentary | 13 | 16.2 |
| | Vegetatively immobile | 46 | 57.5 |
| Climamorphs (Raunkier life forms) | Phanerophytes | 1 | 1.4 |
| | Hamephytes | 2 | 2.5 |
| | Therophytes | 31 | 39.2 |
| | Hemicryptophytes | 34 | 41.4 |
| | Geophytes | 12 | 15.5 |
| Ratio | Therophytes/Geophytes | – | 2.4 |
| | *ITG*, c.u. | – | –0.4 |
| Heliomorphs | Heliophytes | 61 | 74.4 |
| | Scioheliophytes | 19 | 23.2 |
| | Sciophytes | 2 | 2.4 |
| Cenomorphs (by Belgard) | Silvants | 18 | 18.4 |
| | Pratants | 15 | 13.1 |
| | Stepants | 8 | 7.5 |
| | Ruderants | 40 | 36.5 |
| | Adventives | 32 | 24.5 |
| | of which nitrophils (%) | 15 | 14.7 |

*ertianum* L., *Humulus lupulus* L., *Glechoma hederacea* L.), the seeds of which were probably brought by birds or wind from the nearest stands of other purpose (Fig. 1).

It is known that the strategy of the species is a variable throughout the ontogenesis of the individual (Grime 1977; Mirkin et al. 2001). We found that the studied FSB is dominated by species of transitional groups of ecological strategies, in particular plants with CR-strategy (26.5%) (e.g., *A. artemisiifolia* L., *Artemisia vulgaris* L., *Arctium lappa* L., *Linaria vulgaris* Mill., *Elytrigia repens* (L.) Nevsky, *Galium aparine* L.). With CS-strategy (21.7%) there are *Alopecurus pratensis* L., *Arrhenatherum elatius* (L.) J. Presl & C. Presl, *Dactylis glomerata* L., *Agrimonia eupatoria* L., *Anagallis arvensis* L. (ANGAR), *Equisetum fluviatile* L., *Humulus lupulus* L., *Lotus corniculatus* L. With SR-strategy (8.4%) there are *Erodium cicutarium* (L.) L'Hér., *Myosotis arvensis* (L.) Hill., *Trifolium arvense* L. With CRS-strategies (13.3%) there are dominating species *Achillea millefolium* L., *Plantago major* L., *Lolium perenne* L., *Poa trivialis* L., *Sagina procumbens* L., *Torilis japonica* (Houtt.) DC. and *Trifolium repens* L. From the primary-type strategies, explerent species (R-strategists, 26.5%) *Euphorbia peplus* L., *Lamium purpureum* L., *Papaver rhoeas* L., *Persicaria maculosa* S.F. Gray, *Thlaspi arvense* L., *Stenactis annua* (L.) Cass., *Cannabis ruderalis* Juseh dominate. The dominance of explerents among the primary types indicates a violation of the existence conditions for herbaceous species within the territory. At the same time, the number of violents, C-strategists, is the smallest (3.6%) – *Cirsium arvense* (L.) Scop., *Reynoutria japonica* Houtt. and patients are absent. It is established that in all FSB the amplitude according to the shading–lighting regime (Lc) is narrowed and the level of soil moisture (Hd) is increased (Fig. 2).

By bionts in FSB, species of eurivalent fraction (62–65%) with wide amplitude of adaptations to environmental factors dominate. According to the tolerance index to soil conditions, hemistenovalent species and mesovalent species predominate after the eurivalent fraction (almost 30%) (Fig. 3). In total, 29 species of birds of 4 orders nest in the studied FSB, 27 of which are protected by the Bern Convention, 8 are also by the Bonn Convention, 1 additionally – by the Washington and Red Books of Ukraine (Tab. 7). There are no adventive species of birds nesting in FSB.

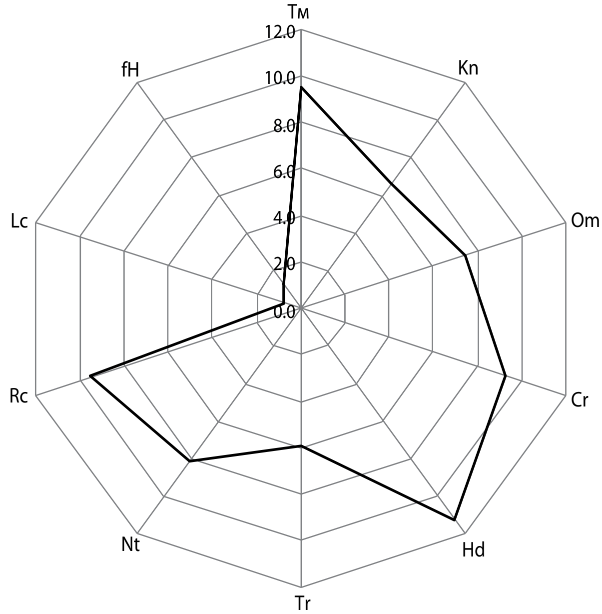


**Figure 2.** Ecological characteristics of the biotope on the phytoindication scales of Tsyganov, points

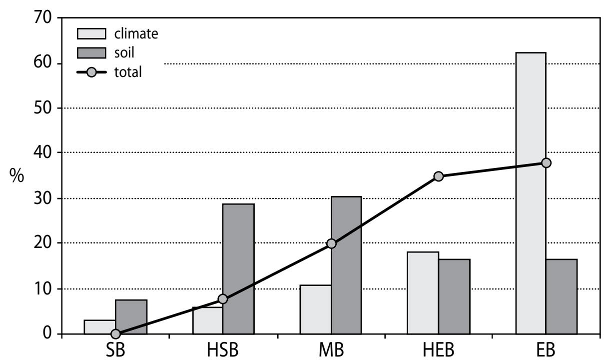


**Figure 3.** The ratio of grass tier species in relation to climatic and soil factors according to the index of ecological tolerance, where SB – stenobionts, HSB – hemistenobionts, MB – mesobionts, HEB – hemieuribionts, EB – euribiont species

Dendrophils reach 93.1%, sclerophiles 6.9% of the species composition of birds ($n$ = 29), which nest in FSB. It should be noted that sclerophiles (*Sturnus vulgaris* L., *Passer montanus* L.) settled only in FSB No. 2 and No. 3. As they are medium-sized hollow-nesting birds, they need full-fledged hollows of appropriate size. Such hollows are usually created in the trees of the first tier. In forest belts, where there are no trees

**Table 7.** Distribution and status of birds nesting in FSB (pairs/ha)

| Species | № FSB | | | | Protected categories |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| *Milvus migrans* Boddaert | | 0.3 | | | Bk2; Bo1,2; W2, RBU |
| *Columba palumbus* L. | | | 1.7 | | – |
| *Streptopelia turtur* L. | | | 3.3 | | Bk3 |
| *Cuculus canorus* L. | | 0.3 | | | Bk3 |
| *Lanius collurio* L. | | 0.6 | | | Bk2 |
| *Lanius minor* Gmelin | | 0.3 | | | Bk2 |
| *Oriolus oriolus* L. | | 0.3 | 1.7 | | Bk2 |
| *Sturnus vulgaris* L. | | 1.7 | 1.7 | | – |
| *Sylvia atricapilla* L. | 1.3 | 0.6 | | 3.3 | Bk2 |
| *Sylvia borin* Boddaert | | 1.4 | | | Bk2 |
| *Sylvia communis* Latham | | 0.3 | 1.7 | | Bk2 |
| *Phylloscopus collybita* Vieillot | 0.6 | 0.6 | 3.3 | | Bk2 |
| *Phylloscopus sibilatrix* Bechstein | | 0.3 | | | Bk2 |
| *Ficedula albicollis* Temminck | | 0.6 | | | Bk2; Bo2 |
| *Muscicapa striata* Pallas | | 0.3 | 1.7 | | Bk2; Bo2 |
| *Phoenicurus phoenicurus* L. | 0.6 | 0.3 | | | Bk2; Bo2 |
| *Erithacus rubecula* L. | 0.6 | 0.9 | 5.0 | 3.3 | Bk2; Bo2 |
| *Luscinia luscinia* L. | 0.6 | 1.7 | | | Bk2; Bo2 |
| *Turdus merula* L. | | 1.7 | 5.0 | | Bk2; Bo2 |
| *Turdus philomelos* C.L. Brehm | 0.6 | 0.6 | 1.7 | | Bk2; Bo2 |
| *Parus caeruleus* L. | 0.6 | 0.9 | 3.3 | | Bk2 |
| *Parus major* L. | 1.9 | 2.9 | 5 | | Bk2 |
| *Sitta europaea* L. | 1.9 | 0.6 | 3.3 | | Bk2 |
| *Certhia familiaris* L. | | 0.6 | 3.3 | | Bk2 |
| *Passer montanus* L. | | 1.4 | 1.7 | | Bk3 |
| *Fringilla coelebs* L. | 1.3 | 2.3 | | 3.3 | Bk3 |
| *Carduelis carduelis* L. | | 0.3 | | | Bk2 |
| *Acanthis cannabina* L. | | 0.3 | | | Bk2 |
| *Emberiza citrinella* L. | | 1.1 | | | Bk2 |

Notes: Bk2, Bk3 – categories of the Berne Convention list; Bo2 – category of the Bonn Convention list; W2 – category of the Washington Convention list; RBU – Red Book of Ukraine.

with thick trunks, sclerophiles are absent. Dendrophils hollow-nesting birds (*Ficedula albicollis* Temminck, *Muscicapa striata* Pallas, *Phoenicurus phoenicurus* L., *Erithacus rubecula* L., *Parus caeruleus* L., *Parus major* L., *Sitta europaea* L., *Certhia familiaris* L.) mostly have a smaller body size and can accommodate nests in hollows of smaller size, and some of them, even in cavities under the bark.

In general, in all FSB hollow-nesting birds occupy the largest share of the group (Fig. 4). A small proportion of crown-nesting birds was found in FSB No. 1, which is also due to the absence of large trees in this stand. However, the high density of shrubs provides good protection for birds that nest on the ground, so their percentage is the highest. In general, the small share of birds that nest on the ground and in the under-

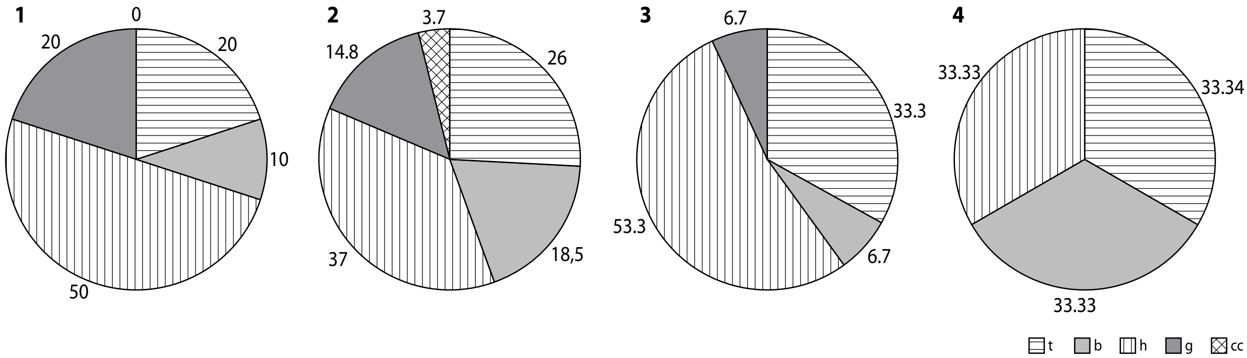


**Figure 4.** Distribution of birds by types of nesting strategy (%): t – crown-nesting, b – nest in understorey, h – hollow-nesting, g – terrestrial, cc – nesting parasite; 1, 2, 3, 4 – FSB

storey in all groups is a sign of significant anthropogenic pressure on the studied forest belts.

FSB No. 2 differs from others by the presence of *Cuculus canorus* L., which is a nesting parasite, the most common hosts of which in forest belts are *Sylvia borin* Boddaert and *Sylvia communis* Latham. These birds nest mainly in FSB No. 2 (Tab. 7).

In all studied FSB, birds of 5 feeding types nest, the spectrum of them is completely presented only in FSB No. 2 (Fig. 5). The most common is a group of birds that feed mainly on invertebrates, which are classified as entomophagous. This is a good sign that the fields will be protected from phytophagous insects along with all FSB. There are not many species that are tertiary consumers. Predators are represented by 1 pair of *Milvus migrans* Boddaert, zoophagous – birds that feed not only on invertebrates but also on small vertebrates – 2 species: *Lanius collurio* L. (2 pairs), *Lanius minor* Gmelin (1 pair).

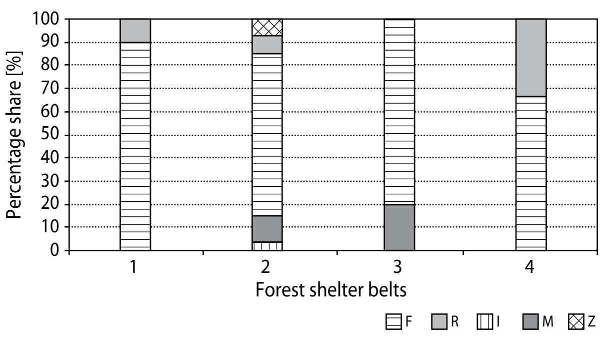


**Figure 5.** Distribution of birds by feeding types (%):
F – predators, Z – zoophages, I – entomophages,
M – phytoentomophages, R – phytophages

## Discussion

FSB in Ukraine is created in accordance with the principles of forest typology. That is, the types of forest crops (phytocenoses) with construction, composition of tree and shrub species that best meet certain types of forest vegetation conditions (ecotope conditions) and better way get harmoniously together, supporting each other, creating a favourable environment for other biota species, as well as a sustainable, productive and durable forest ecosystem in these conditions are selected. However, as a result of land reform and changes in land ownership since the 1990s, the FSB system in Ukraine has not been properly cared for a long time. Forest belts began to be partially destroyed, inhabited by adventive species and lost the designed structure. Thus, they began to reduce the resilience, productivity and ability to perform their target – environmental and protective functions (Furdychko and Lavrov 2009; Lavrov et al. 2019). Causal–consequential relationships for all types of FSB and optimization of their systems have been shown by other researchers (Furdychko and Stadnyk 2012). It has already been proven that the completed multipurpose FSB systems, as a structural part of the multifunctional landscape, are able not only to effectively increase yields of agricultural crops, heterogeneity of the landscape and provide important ecosystem services (carbon sequestration, biodiversity conservation, soil enrichment and erosion prevention, air and water quality improvement), in general they can also provide sustainable land management (Furdychko and Stadnyk 2012; Kedziora 2015; Holland et al. 2017; Udawatta et al. 2019; Buchanan et al. 2020). Landscape heterogeneity of habitats also enhances bird conservation and bird-mediated pest management services in intensive agriculture (Kross et al. 2016). However, we found that in the FSB of Skvyra Research Station, the species composition of nesting birds groups is much lower than in the forests of the region, although the list of dominants is similar in number (Blinkova and Shupova 2018). It is shown that wind-permeable forest belts are a nesting habitat for 18 bird species, dense – for 41, and the largest number of nesting species is characteristic of not dense oak-ash, dense ash and dense mixed forest belts (Kuzmenko 2018). Lack of undergrowth has a negative impact on birds, reproduction and feeding of which is associated with shrubs (Camprodon and Brotons 2006), i.e. for understorey birds. In the studied forest belts their share is low (6.7–18.5%). Therefore, if forest vegetation conditions allow, it is advisable to try to form multi-tiers plantations with shrub understorey. This will increase the functional structure of the forest shelter belt, the volume of its ecological niches, reduce intra- and interspecific competition of birds, will increase the number of nesting pairs per unit area of FSB. Bird nesting in agricultural fields often results in low breeding success (Sviridova et al. 2019). Dense edges in FSB from shrubs provide birds with protection from various dangers and promote realization of reproductive function (Frei et al. 2018; Zingg et al. 2018; Pringle et al. 2019). Such areas are especially relevant for ecotone birds. Dendrophiles that nest on the ground need a well-developed grass cover, the presence of wood mortality, which is the protection of nests. In the absence of woodpeckers nesting in the FSB of Skvyra Experimental Station, the lack of hollows for passive hollow-nesting birds compensates for the hanging of artificial nests (Gaychenko and Shupova 2019). In order to effectively attract insectivorous birds, it is necessary to take into account a number of ecological and ethological indicators: the area of the nesting area protected by the male or pair, which depends on the bird species, population density, nature of the area and interspecific competition.

Grass and understorey tiers, in addition to the important ecological role for birds and other animals, determine the natural regeneration of tree species, are the main centers of floral diversity and an indicator of forest ecosystems stability (Zhukova et al. 2010; Didukh 2012; Budzhak et al. 2019). The close interdependence of the tree and grass-shrub tier, their composition and structure determine the direction of the succession process in forest ecosystems (Hidding et al. 2013). In the grass cover of the studied FSB, the largest number of species has a low frequency of occurrence (till 18%) with a significant proportion of ruderals and adventive species. The problem of biological invasions is considered today as one of the threats to biodiversity, especially native species and communities (Protopopova et al. 2006; Burda and Koniakin 2019; Lavrov et al. 2019; Budzhak et al. 2019). The last stages of anthropogenic transformation of phytocenoses are characterized by the dominance of species with transitional and mixed types of strategies (Huseinova et al. 2013, Lavrov et al. 2019). The grass tier of the studied forest belts is dominated (61.5%) by species of mixed strategies.

## Conclusion

Thus, the studied field protective forest shelter belts are significantly transformed due to long-term lack of care. This is evidenced by the structure of species in phytocenoses: the dominance of adventive species-transformers in the stand; adventive species (24.5%) and ruderants (36.5%), violation of heliophyte ratios and the presence (14.7%) of nitrophils, as well as species with a mixed life strategy (60%) in the grass tier. The latter species indicate changes in soil moisture and trophic conditions. Only in 2–7-row, wider and dense forest shelter belts, an edificatory tier with the density of canopy 0.72–0.81 and a biologically favourable environment were formed. This occurred as a result of the natural reorganization of the structure of stands by changing the weakened dominant trees with accompanying species and the invasion of other species. Narrower, wind-permeable, semi-permeable with gaps degraded forest shelter belts do not sufficiently perform environmental functions and other ecosystem services. In the studied landscape, the species composition, ecological and trophic structure of the ornithocomplex is depleted, except for only a three-tier, dense forest belt with developed shrub understorey. This is due to the lack of a complete complex of suitable and protected nesting stations. The lack of many species on nesting has a negative impact on the spectrum of bird nutrition in degraded forest shelter belts, and, accordingly, on the full protection of fields from entomo-pests. To attract insectivorous birds it is necessary to take into account their species, ecological and ethological properties, population density, the nature of habitats and features of interspecific competition.

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