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CONSERVATION OF INVERTEBRATES' BIODIVERSITY IN SOILS OF THE REPUBLIC OF MOLDOVA

IRINA SENICOVSCAIA¹

Abstract. *The role of invertebrates and their contribution in functioning of soils is considered. The edaphic fauna of zonal untouched soils in natural ecosystems located in the different zones of the Republic of Moldova has been investigated. Soils of the natural ecosystems are the habitat and the source of the conservation and reproduction of the edaphic fauna. They represent themselves the standards of the biodiversity for soil invertebrates. The database of the invertebrates' diversity of virgin and fallow soils has a practical importance as the natural standard for the operative evaluation of degradation processes and ecological effectiveness of the land management. Agricultural practices with the involvement of areas with multiannual grasses in a crop rotation system created conditions for the improvement of the invertebrate's biodiversity in the chernozem which degraded as a result of a long-term arable use. The use of ryegrass and lucerne mixture during 3-5 years helps to restore the soil invertebrates at the expense of exudates contribution in the soil and roots of perennial crop residues. This procedure has promoted the revival of population of invertebrates. The number of invertebrates on average was 2.5 times higher compared with the control, the total biomass – by 1.6 times. This method is especially effective to restore the Lumbricidae family. Their number increased by 3.0 and biomass – by 2.0 times. The recovery rate of the population of Lumbricidae family reaches of 14.9 ex m⁻² per year. Invertebrates' diversity has been improved, the number of invertebrates' families increased from 2-4 to 5-6.*

Key-words: soil invertebrates, biodiversity, conservation, humus, perennial grasses

INTRODUCTION

The primordial importance of the biodiversity for the environment maintaining stability and the stable development of communities is reflected in the Convention on Biological Diversity [9]. Invertebrates' diversity is one of the most important evaluation criteria of soil ecosystems [8, 12 and 14], resistance to different forms of degradation [11 and 13]. In some ecosystems, the local diversity of soil fauna may be more enormous, then the diversity of different groups of aboveground plants or animals [10]. Excessive reduction of the soil biodiversity, especially the loss of keystone species and/or species with unique functions may have some cascading ecological effects, which lead to the long-term deterioration of soil fertility and the loss of agricultural productive capacity [2 and 6]. Soil biodiversity also can have indirect effects as to whether soil functions as a carbon sink or source.

Soil invertebrates present an important trophic level in the ecological chain nutrition of the biocenosis. Invertebrates have a great importance for biological processes in soil, increase the fertility and humus formation by mechanical decomposition of plant residues and formation of water-stable soil structure [4, 5, 6, 7 and 11].

Indices of soil invertebrates are the global indicators of soil quality and sustainability of ecosystems. The preservation of soil ecosystem services largely depends upon the preservation of soil invertebrates. This may be achieved by using of environmentally friendly agricultural technologies based on the utilization of perennial grasses.

The purpose of the research was to investigate the invertebrates in different soils of natural ecosystems and to determine the influence of the perennial legume-cereal grass mixtures cultivation on the invertebrates' recovery process for the biodiversity conservation, improvement of the stability and environmental certifications of chernozems degraded as the result of the long-term agricultural utilization.

MATERIAL AND METHODS

Experimental sites and soils. Our comparative study has been performed in different zones of the Republic of Moldova. The content, biomass, profile distributions and diversity of

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invertebrates in zonal untouched soils in natural ecosystems were investigated. Investigations were performed on the typical, leached, ordinary, xerophyte-forest chernozem and the gray forest soil. Additionally, the state of invertebrates in the two zonal arable soils (leached and ordinary chernozem) was compared. Land management practices with the application of perennial grasses (ryegrass+lucerne) in the condition of long-term field experiments have been analyzed. Researches were carried out during the period between 2009 and 2012 years.

The first site was located in the center of the country, in the Ivanča village, Orhei region. The long-term arable soil with crop rotation without fertilizers (control), and grass mixtures (ryegrass and lucerne) cultivation was tested. Plots under mixtures of perennial grasses were founded in the autumn of 2007. The soils were the leached chernozem with humus content of 3.43 % and pH = 6.6 and the gray forest soil with humus content of 2.40 % and pH = 6.4 in the 0-25 cm layer.

The second site was located in the southern zone, in the Tartaul de Salchie village, Cahul region. These were the plots with long-term arable soil (control) and with the mixture of ryegrass and lucerne. Plots under mixtures of perennial grasses (ryegrass+lucerne) were founded in the spring of 2010 year. The soil was the ordinary chernozem with humus content of 3.16 % and pH = 7.1 in the 0-25 cm layer [3].

Status of invertebrates. The state of invertebrates was identified from test cuts by manually sampling the soil layers to the depth of soil fauna occurrence applying Gilyarov and Striganova's method [5]. The identification of invertebrate's diversity on the level of families and their classification according to nutrition were carried out with the implementation of Gilyarov and Striganova's method [5]. The zoological indices were evaluated statistically using the variation analysis.

Soil chemical properties. Organic C was analyzed by the dichromate oxidation method. The humus content was calculated using the coefficient of 1.724 [1]. Sampling was carried out per soil horizons and from 0 - 30 cm layer separately.

Soil physical properties. The structure-aggregate composition of the soil was determined by the method of Savinov, the bulk density was analyzed by the cylinders' method [15]. Sampling was carried out per soil horizons.

RESULTS AND DISCUSSIONS

Invertebrates in soils of the natural ecosystems. The use of soils with the natural vegetation cover, which is in equilibrium with the environment, as a standard, offers the opportunity to assess the level of the resistance and quality of degraded soils. Virgin and fallow soils are the medium for conservation and reproduction of various species of invertebrates. Invertebrates of virgin and fallow soils exist in conditions of the high supply of organic matter and its conservation within the limits of the ecosystem. As a consequence, soils in conditions of the natural ecosystems are characterized by a higher abundance, biomass and diversity of soil invertebrates in comparison with arable soils [13].

Soils in natural ecosystems possess the favorable physical and chemical properties and they are the standard of the edaphic fauna's composition and activity. A good example of the soil-standard for soils located in the south of the country can be the xerophyte-forest chernozem. This chernozem has the high content of organic carbon in the top layer (6.27%) and the favorable physical status for the plant growth (Table 1). The xerophyte-forest chernozem is characterized by the high content of agronomic valuable aggregates, reaching 76.0% in the upper horizon; its structure coefficient is 3.2. In fact, the top layer of the soil-standard consists of a layer of coprolites of earthworms; it has an excellent water-stable structure.

The largest share of invertebrates in soils-standards (88.2-91.8%) and *Lumbricidae* family (77.8-78.7%) is concentrated in the 0-10 cm layer of soil and in the debris layer (Figure 1).

The soils of natural ecosystems are characterized by the highest diversity of invertebrates. The edaphic fauna in soils-standards is represented mainly by the *Lumbricidae* family (30.4-

75.6%). In addition to earthworms, species from the families of *Formicidae*, *Glomeridae*, *Carabidae*, *Araneae*, *Cerambycidae*, *Apidae*, *Forficulidae*, *Coccinellidae* and other have been found in the soils of natural ecosystems (Table 2). The soil under the natural vegetation contains 5-12 families of invertebrates.

Table 1. Physical and chemical properties of the xerophyte-forest chernozem (virgin land)

Genetic horizon and depth, cm	Humus content, %	Organic C, %	Bulk density, g cm ⁻³	Aggregates content (%) with the diameter (mm)			K _s **
				>10	Σ 10-0.25	<0.25	
Ahd 0-10	10.80	6.27	1.00	$\frac{18.0^*}{9.8}$	$\frac{76.0}{76.0}$	$\frac{6.0}{14.2}$	3.2
Ah 10-61	4.45	2.59	1.21	$\frac{48.2}{0}$	$\frac{48.2}{73.8}$	$\frac{3.6}{26.2}$	0.9
ABh 61-80	2.81	1.63	1.20	$\frac{39.4}{0}$	$\frac{55.5}{56.4}$	$\frac{5.1}{43.6}$	1.2

* numerator - dry sieving, denominator - wet sieving

** structure coefficient

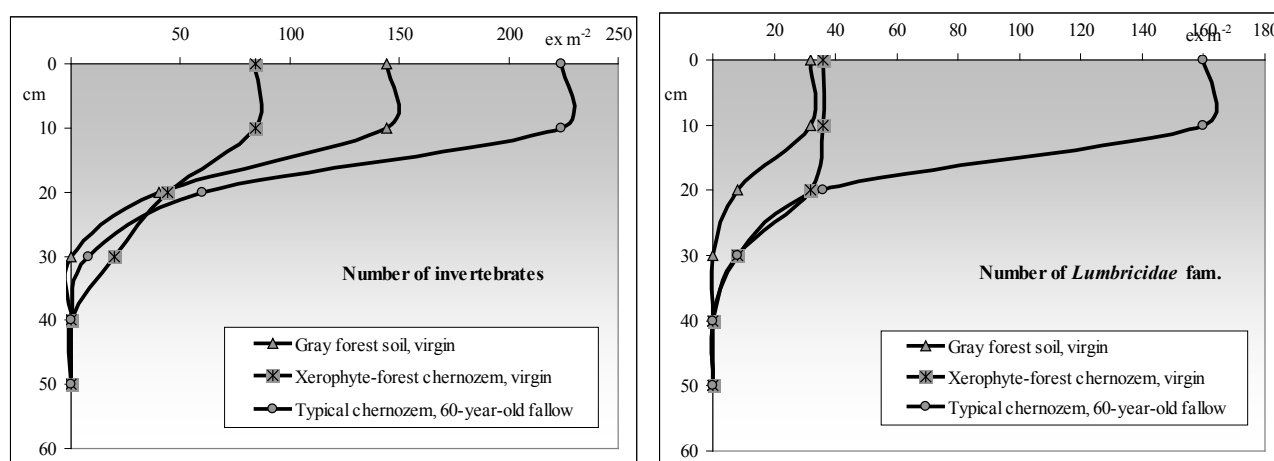


Figure 1. The profile distribution of invertebrates in soils-standards

The soils in the Forest Kodry Zone are characterized by the highest diversity of invertebrates compared to soils located in the Plain Steppe Zone. The virgin gray forest soil contains 12 families and 15 species of invertebrates, fallow leached chernozem – 10 families and 12 species of invertebrates. The smaller number of families and species were found in the soils at the south: the virgin xerophyte-forest chernozem contains 6 families and 7 species, the ordinary chernozem under fallow - 5 families and 5 species of invertebrates. The families of *Lumbricidae*, *Glomeridae* and *Formicidae* are present in all investigated soils. Species of *Pentatomidae* and *Pieridae* families are found only in the xerophyte-forest chernozem; *Araneae* – in the leached chernozem; *Annelidae* and *Geophilidae* – in the gray forest soil.

The following species have been detected in the virgin gray forest soil: *Lumbricus terrestris*, *Eisenia foetida*, *Glomeris marginata*, *Diplopoda* *D. B. lainville*, *Dorcadion fulvum*, *Eurygaster maura*, *Bombus terrestris*, *Carabus convexus*, *Scelopendra cingulata*, *Coccinella septempunctata*, *Galeruca tanacetii*, *Blaps mucronata*, *Formica rufa* et al. The leached chernozem is characterized by species of *Lumbricus terrestris*, *Glomeris marginata*, *Bombus terrestris*, *Carabus convexus*, *Aegosoma scabricornis*, *Diplopoda* *D. B. lainville*, *Forficula auricularia*, *Formica rufa*, *Theridium ovatum*, *Coccinella septempunctata*, *Harpalus hirtipes* et al. Species of *Lumbricus terrestris*, *Glomeris marginata*, *Diplopoda* *D. B. lainville*, *G. raphosoma lineatum*,

Prionus coriarius, *Pieris brassicae*, *Formica rufa* are dominated in the xerophyte-forest chernozem. The ordinary chernozem under fallow is characterized by the smaller number of species: *Lumbricus terrestris*, *Glomeris marginata*, *Forficula auricularia*, *Formica rufa*, *Crysomela violacea*.

Table 2. Diversity of soil invertebrates in natural ecosystems in the Republic of Moldova (ex m⁻²)

No	Family	Gray forest soil, virgin land	Leached chernozem, 40-60-year-old fallow land	Xerophyte-forest chernozem, virgin land	Ordinary chernozem, 55-year-old fallow land
1	<i>Lumbricidae</i>	38.4	20.5	78.3	340.2
2	<i>Glomeridae</i>	50.3	11.1	37.4	83.7
3	<i>Annelidae</i>	2.4	0	0	0
4	<i>Cerambycidae</i>	2.4	10.1	4.1	0
5	<i>Scutelleridae</i>	1.3	0	0	0
6	<i>Apidae</i>	1.4	6.9	0	0
7	<i>Carabidae</i>	2.0	4.0	0	0
8	<i>Geophilidae</i>	1.1	0	0	0
9	<i>Coccinellidae</i>	4.5	2.5	0	0
10	<i>Crysomelidae</i>	1.1	0	0	4.5
11	<i>Tenebrionidae</i>	1.1	6.9	0	0
12	<i>Forficulidae</i>	0	2.5	0	21.6
13	<i>Formicidae</i>	+++	+++	+++	+++
14	<i>Araneae</i>	0	2.5	0	0
15	<i>Pentatomidae</i>	0	0	4.1	0
16	<i>Pieridae</i>	0	0	4.1	0
Total		106.0	67.0	128.0	450.0

The greatest number in the total amount of invertebrates represents saprophages. They comprised 88.6% of the total number of invertebrates in the gray forest soil; 55.2% – in leached chernozem under fallow; 90.8% – in the xerophyte-forest chernozem; 94.2 % – in the ordinary chernozem under fallow. The leached chernozem under fallow in comparison with other soils are characterized by the highest number of species which are the part of phytophages – 16.4%, zoophages – 7.4 %, necrophages – 15.0 %, predators – 6 %. Groups of necrophages and zoophages were registered only in soils of the Forest Kodry Zone. The maximum number of invertebrates with the mixed type of nutrition were observed in the ordinary chernozem. Ecological pyramids were more stable in soils of the Forest Kodry Zone.

The share of earthworms in the total abundance of invertebrates constitutes of 35.3-75.9 % and their biomass – 59.1-89.0 % in the soils of natural ecosystems. It should be noted the tendency towards increasing the share of *Lumbricidae* family in the total number of invertebrates in the direction from the north to the south of the country. The weight of one exemplar of *Lumbricidae* family in chernozems constitutes 0.22-0.27 g, in the gray forest soil – 0.5 g (Figure 2).

The abundance of invertebrates in soils under the natural vegetation is provided by the high level of the organic matter content. The humus content (confidence intervals, $P \leq 0.05$) constitutes: 4.0-5.7 % in the gray forest soil, 4.9-5.1 % in the typical chernozem, 3.7-4.6 % in the leached chernozem and 3.8-4.0 % in the ordinary chernozem.

The soil biota's composition in natural ecosystems is complex and diverse. Forests and field-protective belts are the medium for the conservation and restoration of the diversity and abundance of invertebrates. Therefore, the conservation of soil – standards in protected zones is important not only in terms of the protection of environment, but it has also significant scientific information.

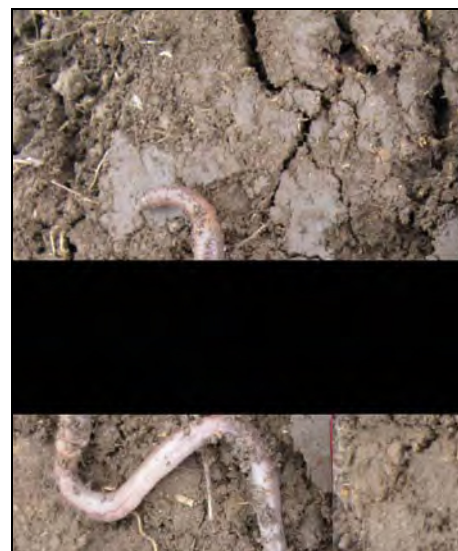
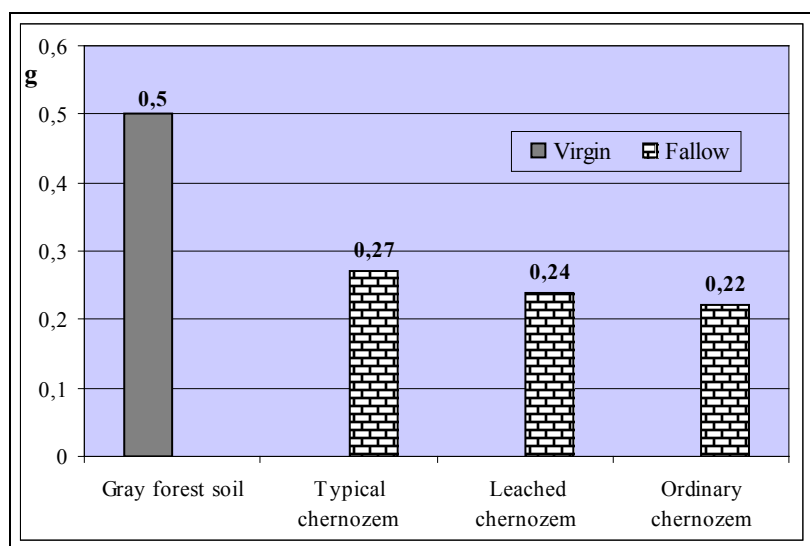


Figure 2. The average weight of 1 representative of the *Lumbricidae* family (n=3-32)

The influence of perennial grasses on soil invertebrates. The application of perennial legume-cereal grass mixtures led to the restoration of the total number of invertebrates and the *Lumbricidae* family. The post-restoration recovery of the invertebrate community is slow. The biomass of populations under grass mixture (1-2 year-old) was smaller than those under traditional arable management, but the number of invertebrates sometimes was significant. This demonstrates the reproduction of young invertebrates' populations and the occurrence of the initial stage of successional changes.

Statistically significant growth of zoological indicators has been registered after the third year of investigations on plots with grass mixtures of ryegrass and lucerne (Table 3). The number of invertebrates on average was 2.5 times higher in comparison with the control plot, the total biomass – 1.6 times respectively.

Table 3. Status of soil invertebrates under the application of perennial grasses (12.05. 2010)

Variant	Number of invertebrates, ex m ⁻²		Biomass of invertebrates, g m ⁻²	
	total	<i>Lumbricidae</i> fam.	total	<i>Lumbricidae</i> fam.
Gray forest soil				
Control plot (arable, winter wheat)	32.0	32.0	2.2	2.2
Ryegrass+lucerne (3-year-old)*	149.0	117.0	19.5	14.7
LSD 5%	105.5	75.0	15.6	12.3
Leached chernozem				
Control plot (arable, winter wheat)	40.0	28.0	5.2	2.8
Ryegrass+lucerne (3-year-old)*	128.0	104.0	28.4	22.3
LSD 5%	82.2	72.4	21.1	21.0

* Plots under mixtures of perennial grasses were founded in the autumn of 2007

This method is especially effective for restoring the *Lumbricidae* family. Earthworm populations in the grass cultivation by ryegrass and lucerne during 3-5 years were significantly larger than those exposed to the arable management, both in terms of earthworm abundance and biomass. Their number in the leached chernozem increased by 3.0 and biomass – by 2.0 times. The

population growth over 5 years constitutes 74.4 ex m^{-2} ($744.000 \text{ ex ha}^{-1}$) or 14.9 ex m^{-2} ($149.000 \text{ ex ha}^{-1}$) annually.

The process of the recovery of the soil invertebrates' diversity and activity in arable lands has been slow. There was the gradual increase in the number of worms after 1-2 years of the cultivation of mixtures with ryegrass and lucerne, but significant changes in the diversity of invertebrates has been not fixed (Table 4). The significant presence of ants was registered on plots with perennial grasses.

Table 4. Diversity of soil invertebrates in the ordinary chernozem under the grass mixtures cultivation

Variant	Family	Number of invertebrates, ex m ⁻²	
		families	total
17-18.05.2011			
Control (arable)	<i>Lumbricidae</i>	20.0	48.0
	<i>Geophilidae</i>	4.0	
	<i>Pieridae</i>	12.0	
	<i>Elateridae</i>	8.0	
	<i>Scarabaeidae (larvae)</i>	4.0	
Ryegrass+lucerne (1 years old)*	<i>Lumbricidae</i>	12.0	20.0
	<i>Elateridae</i>	4.0	
	<i>Pieridae</i>	4.0	
	<i>Enchytraeidae</i>	+	
	<i>Formicidae</i>	+++	
20.09.2011			
Control (arable)	<i>Lumbricidae</i>	8.0	16.0
	<i>Coccinelidae</i>	8.0	
Ryegrass+lucerne (1 years old)*	<i>Lumbricidae</i>	32.0	32.0
	<i>Formicidae</i>	+++	
24.04.2012			
Control (arable)	<i>Lumbricidae</i>	12.0	28.0
	<i>Apidae</i>	4.0	
	<i>Coccinelidae</i>	12.0	
Ryegrass+lucerne (2 years old)*	<i>Lumbricidae</i>	76.0	92.0
	<i>Scarabaeidae (larvae)</i>	4.0	
	<i>Pieridae</i>	4.0	
	<i>Carabidae</i>	4.0	
	<i>Formicidae</i>	+++	
	<i>Unidentified sp.</i>	4.0	

* Plots under mixtures of perennial grasses were founded in the spring of 2010

The grass cultivated soil is characterized by the greater diversity of invertebrates after 3-5 years of growing ryegrass and lucerne. In addition to the *Lumbricidae* family, species of the *Formicidae*, *Glomeridae*, *Scarabaeidae*, *Elateridae*, *Geophilidae*, *Aranidae*, *Coccinelidae* and *Carabidae* families were found (Table 5). The abundant presence of the *Formicidae* family representatives is observed. In general, the soil under grass mixture with ryegrass and lucerne contains 5-6 families of invertebrates, while the soil under arable only 2-4 families of edaphic fauna.

Table 5. Diversity of soil invertebrates in the leached chernozem in conditions of the application of mixtures with ryegrass and lucerne

Variant	Family	Number of invertebrates, ex m ⁻²	
		families	total
12.05.2010			
Control (arable)	<i>Lumbricidae</i>	28.0	40.0
	<i>Glomeridae</i>	4.0	
	<i>Tenebrionidae</i>	4.0	
	<i>Enchytraeidae</i>	4.0	
Ryegrass+lucerne (3 year old)*	<i>Lumbricidae</i>	104.0	128.0
	<i>Elateridae</i>	5.3	
	<i>Tenebrionidae</i>	10.7	
	<i>Coccinelidae</i>	2.7	
	<i>Pieridae</i>	5.3	
	<i>Formicidae</i>	+++	
13.09.2011			
Control (arable)	<i>Lumbricidae</i>	20.0	56.0
	<i>Glomeridae</i>	32.0	
	<i>Carabidae</i>	4.0	
Ryegrass+lucerne (4 year old)*	<i>Lumbricidae</i>	152.0	184.0
	<i>Glomeridae</i>	16.0	
	<i>Carabidae</i>	12.0	
	<i>Coccinelidae</i>	4.0	
	<i>Formicidae</i>	+++	
14.06.2012			
Control (arable)	<i>Lumbricidae</i>	44.0	60.0
	<i>Glomeridae</i>	8.0	
	<i>Coccinelidae</i>	8.0	
Ryegrass+lucerne (5 year old)*	<i>Lumbricidae</i>	84.0	100.0
	<i>Glomeridae</i>	4.0	
	<i>Coccinelidae</i>	8.0	
	<i>Carabidae</i>	4.0	
	<i>Formicidae</i>	+++	

* Plots under mixtures of perennial grasses were founded in the autumn of 2007

Lumbricus terrestris and *Allolobophora terrestris* species are the most typical representatives of the *Lumbricidae* family in the chernozem under perennial grasses. Should be noted that the recovery rate of the *Lumbricidae* family consists of 14.9 worms m⁻² per year on plots under mixtures with ryegrass and lucerne after 3-5 years, whereas the regeneration of worms on soils under the natural recreation reaches only of 3.0-5.6 worms m⁻² per year.

In general, zoological parameters (by some indicators) have reached the level of soils under natural vegetation.

The humus content level was higher on plots under perennial grasses by 0.2-0.3 % in comparison with arable plots [3]. Thus, the farming system with the application of ryegrass and lucerne greatly improves the status of invertebrates and fertility of arable soils.

CONCLUSIONS

The soils of the natural ecosystems are the habitat and the source of the conservation and reproduction of the edaphic fauna. They are the standards of the biodiversity for soil invertebrates. Saprophages constitute 88.6%–94.2% of the total abundance of invertebrates, their main biomass is

accumulated in the upper soil horizons. The families of *Lumbricidae*, *Glomeridae* and *Formicidae* are usually present in all investigated soils. *Pentatomidae*, *Pieridae* and *Araneae* families are rarely encountered. Soils in the Forest Kodry Zone are characterized by the highest diversity of invertebrates compared to soils located in the Plain Steppe Zone. On the whole 19 species of invertebrates (from them 11 rare species) have been identified in soils of this zone. 9 species of invertebrates (from them 4 rare species) have been detected in chernozems of the Plain Steppe Zone. A stable state of the soil invertebrates is provided by a topsoil humus content of 4.0-6.0 % and favorable physical properties of soils. The database of the invertebrates' diversity of virgin and fallow soils has a practical importance as the natural standard for the operative evaluation of degradation processes and ecological effectiveness of the land management.

The effective restoration of the biota in degraded arable chernozems occurs as a result of the cultivation of perennial grasses. Perennial grass mixtures with ryegrass and lucerne can be used in arable soils to create oases and migration corridors for the soil biota. The restoration of the lost components of the soil biota in the long-term arable chernozems is a long process. The reproduction of young populations of invertebrates in conditions of the application of perennial grasses during 1-2 years testifies the initial phase of the biota's succession. The use of the mixture of ryegrass and lucerne during 3-5 years has resulted to the growth of the number of invertebrates and *Lumbricidae* family by 2.5 and 3.0, to their biomass – by 1.6-2.0 times in comparison with the traditional arable management. Invertebrates' diversity has improved, the number of invertebrates' families increased from 2-4 to 5-6. The annual population growth of earthworms reaches of 14.9 ex m⁻².

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