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ECOLOGICAL NICHES AND SPATIAL DISTRIBUTION OF SOIL MESOFAUNA IN SODDY-LITHOGENIC SOILS ON LOESSIAL SANDY LOAMS: CASE OF NIKOPOL MANGANESE ORE BASIN

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Abstract: The paper presents the spatial distribution and quantitative characteristics of ecological niches soil mesofauna of soddy-lithogenic soils on loess land reclamation of Nikopol manganese ore basin. It was established that edaphic characteristics of soddy-lithogenic soils on loess loam and vegetation characteristics (ecomorphs and using phytoindication scale) describe 87.71% of the variation of the spatial distribution of soil animals. With RLQ-analysis revealed two axes of differentiation of animal populations that are integral evaluation of the entire set of environmental factors. Axis 1 describes 62.81%, and the axis 2 - 18.90% of the spatial variability of distribution mesofauna. There was a statistically significant marginal 3 species (O. sabulosum, A. rosea, A. trapezoides) of 21, which speaks of the non-random choice of habitat preference of these species-specific conditions for life. The functional groups of soil animals, marked by a cluster analysis on the basis of the relationship of ecomorphs structure and environmental factors reflect the differentiation of ecological niches of individual groups of species which are sensitive to hardness, soil temperature and projective cover plants. Reflection axes RLQ-analysis in the geographic space show that the study of the landfill is not uniform for soil animal.
Keywords: ecomorphs, reclamation, soil mesofauna, ecological niches

1. INTRODUCTION

The soil mesofauna is a faunistic complex consisting of large invertebrates. The importance of studying populations of soil invertebrates is due to their enormous role in the life of soil, where they not only live, but also actively form the structure of soil horizons. Soil's representatives of mesofauna are involved in many of soil formation processes and are essential of ecosystem engineers (Lavelle *et al.*, 1997).Uneven spatial distributions of the soil fauna is one of the most important characteristics of their reactions to environment factors (Pokarzhevsky, 2007). It is so-called "environmental standard" according to (Gilyarov, 1965) - the needs of each species in a certain complex environmental conditions. The environmental factors influence the species distribution, usually the space is structured and therefore societies have also the spatial structure (Dray *et al.,* 2006). Habitat is characterized by the presence in certain areas of resources and conditions necessary to species to survive, reproduce and successfully and competitively fight.(Hall *et al.,* 1997).

Zoological diagnosis of soils is the establishment of conformity and data communication between the typological units of soil cover and emergent properties of soils animal population (Zhukov, 2009). Soil-zoological studies allow to use soil animals for the characterization of soil conditions and their changes from technogenic or economic impacts. Zoological technozems diagnostics is promising and represents a relevant issue in the use of recultivated soils (Gilyarov, 1965; Zhukov, 2009). The study of spatial distribution of soil mesofauna in the soddy-lithogenic soils allows diagnosing soil data, evaluating the impact of various environmental factors, and revealing interrelations of vital activity soil animals and modes of soil processes.

The purpose of the present work was to quantify the ecological niches of the soil fauna landfill on soddy lithogenic soils formed on the loess loams on the basis of RLQ- and OMI-analyses.

2. MATERIAL AND METHOD

Material is selected on the reclamation site of Dnepropetrovsk State Agrarian University of Nikopol manganese ore basin (see Figure1) (Dnipropetrovsk region, the city of Ordzhonikidze) in April-May 2012. Samples were collected in a soddy-lithogenic soils formed on loessial sandy loams. Material is selected at a regular grid - 7 transect at 15 of samples each, a total of 105 samples. The lag between transects and samples is of 3 m. At each point were made soil-zoological samples for collecting a soil mesofauna, carried out the measurement temperature, conductivity and hardness of the soil, litter thickness and height of herbage (R-table). Soil-zoological samples had a size of 25×25 cm. Hardness measurement of soils performed in the field conditions using manual penetrometer Eijkelkamp on depth to 50 cm at an interval of 5 cm. The average error of measurement results of the instrument is ± 8%. The measurements were carried out with a cone sectional dimension 2 cm^2 within each measurement point of hardness of soil were carried out in triplicate. To make measurement of soil electrical conductivity was used in situ a sensor HI 76305 (Hanna Instruments, Woodsocket, RI). This sensor operates in conjunction with a portable device HI 993310. Tester assesses the overall electric conductivity of the soil, i.e. integrating the soil air, water and particles. The measurement results are presented in units of the device of the soil saturation with salts solution of - g / l. Comparison of the results measurements with HI 76305 with laboratory data allowed us to estimate the conversion factor units as 1 dC / m = 155 mg / l (Pennisi and Iersel, 2002).

Figure 1. Map of the study area location

The soil temperature was measured from 13 to 14 hours of digital thermometers WT-1 (PJSC "Steklopribor», http://bit.steklopribor.com, precision – 0.1°C) at a depth of 5-7 cm. Measurements of electrical conductivity and temperature made in triplicate at each test point. Aggregate soil composition was determined by dry sieving by Savinov (Dospehov, 1979). Soil samples were selected from the top layer 0-10 cm. The physiognomic types of flora are highlighted on the basis of spectral reflectivity of digital images surfaces vegetation cover, which can be conditionally be characterized as: 1-Poáceae; 2-Umbellíferae; 3-Asteraceae; 4-Fabáceae; 5-deadwood; 6-soil. Phytoindication scales of vegetation are presented by (Tsyganov, 1983). Characteristic of ecomorphs plants shown by (Belegarde, 1971; Tarasov, 2005), Q-table is presented ecomorphs of soil animals (Zhukov, 2009).

3. RESULTS

Edaphic characteristics can be considered as determinants of ecological space communities of soil mesofauna (Table 1). Corresponding to the analysis of obtained data, the predominant fraction is aggregates of 2-3, 3-5 mm. Other fractions are characterized by participation in the aggregate structure at 4.08-10.44%. The average value of hardness regularly increases with depth. At the toplayer of a depth of 5 cm hardness is at a level of 4.08 MPa. According to literature data (Bathke et al., 1992), growth of plant roots stops at resistance of 0.8-5 MPa. Penetrometer Readings higher than 5 MPa, indicates a compacted soil which counteracts the root growth (Faechner *et al*., 1999). From a depth of 5 to 50 cm hardness gradually increased from 6.18 to 10.44 MPa. It was recorded that the average value of electrical conductivity is 0.51 S / cm. The average temperature of sod-lithogenic soils on red-brown clays at time of measurement in 03.05.2012 was 17.22 ºC. On 20.06.2012, the average temperature is equal to 34.35 ºC. According to Phytoindication scales the thermo-climate investigated ecotopenemoral (46.1 kcal / cm * cm * year), Continental - mainland; ombro-climate - sub-humid (P-E = - 305 mm / year, P - precipitation mm / year, E - evaporation mm / year); crio-climate - mild winters / mild winters; humidity - Average steppe type; common mode of soil salinity and trophic - rich / saline soils; nitrogen nutrition - poor soil nitrogen; soil acidity - slightly acidic / neutral soils; light conditions - open / semi-open spaces. The ecomorphic analysis of vegetation in coenomorphes aspect is characterized by a predominance of steppe (72%).

Ecological optimum hygromorphes (Matveev, 2003) is 2.13 - fresh type of the regime trophomorphes - 2.88 and also corresponds to moderately fertile soils, and geliomorph - 2.21, which shows in the penumbral regime type. According to analysis results shown in Table RLQ 2 and Figure 3, it was established that 81.71% of the variation (of total inertia) describe the first two axes RLQ (62.81 and 18.90%, respectively).

Table 1. Determinants of ecological space of the soil mesofauna

Medium parameters	Average	Confidence interval – 95 %	Confidence interval + 95 %	CV, %	RLQ axis 1	RLQ axis 2
Soil structure, size fraction,%						
>10 mm	7.30	6.31	8.29	69.91	0.09	–0.03
7–10 mm	6.04	5.65	6.43	33.37	–0.01	–0.21
5–7 mm	9.48	8.01	10.94	80.06	0.16	–0.22
3–5 mm	19.06	17.93	20.19	30.63	–0.06	–0.14
2–3 mm	40.67	38.83	42.50	23.30	–0.17	0.11
1–2 mm	5.24	4.66	5.81	56.46	0.01	0.13
0.5–1 mm	6.51	5.87	7.16	51.37	0.00	0.24
0.25–0.5 mm	5.71	5.15	6.26	50.18	0.09	0.28
<0.25 mm	7.30	6.31	8.29	69.91	0.09	–0.03
Hardness at depth soil, MPa						
0–5 cm	4.08	3.71	4.45	46.70	0.27	–0.39
5–10 cm	6.18	5.68	6.67	41.71	0.38	–0.65
10–15 cm	7.17	6.67	7.67	36.21	0.33	–0.72
15–20 cm	7.84	7.28	8.41	37.05	0.38	–0.73
20–25 cm	8.54	7.91	9.16	37.67	0.38	–0.76
25–30 cm	9.01	8.31	9.72	40.28	0.40	–0.71
30–35 cm	9.23	8.41	10.05	45.80	0.37	–0.73
35–40 cm	9.55	8.67	10.43	47.70	0.40	–0.66
40–45 cm	10.04	9.05	11.02	50.79	0.42	–0.62
45–50 cm	10.44	9.37	11.52	53.11	0.41	–0.60
Physical properties and humus content						
Electrical conductivity, S /m	0.51	0.48	0.54	29.41	0.20	0.28
Temperature 03.05.12	17.22	17.05	17.39	5.12	–0.54	–0.16
– 20.06.12	3435	33.78	34.92	8.54	–0.12	–0.50
Physiognomic vegetation types						
Type_1	0.09	0.08	0.10	46.00	0.34	–0.05
Type_2	0.17	0.16	0.19	42.67	–0.20	–0.46
Type_3	0.13	0.12	0.14	47.99	0.44	–0.25
Type_4	0.06	0.05	0.07	70.34	–0.20	0.02
Type_5	0.12	0.11	0.12	26.06	0.37	–0.06
Type_6	0.43	0.40	0.46	35.83	–0.19	0.33
TsyganovPhytoindication assessments						
Tm	9.24	9.18	9.30	3.20	–0.35	–0.45
Kn	9.24	9.18	9.30	3.20	0.78	0.64
Om	9.21	9.15	9.27	3.22	–0.78	–0.62
Cr	8.71	8.65	8.77	3.51	0.77	0.64
Hd	7.61	7.53	7.68	5.04	–0.77	–0.49
Tr	10.27	10.06	10.47	10.28	0.84	0.56
Nt	5.59	5.49	5.68	8.82	0.79	0.57
Rc	8.83	8.79	8.86	2.06	0.16	–0.23
Lc	2.21	2.17	2.25	9.40	–0.81	–0.62
A.L Belgard Ecomorphs						
Hygr	2.13	2.11	2.14	3.56	–0.31	0.02
Troph	2.88	2.86	2.90	3.10	0.18	–0.19
St	0.72	0.71	0.73	6.80	–0.74	–0.55
Pr	0.04	0.03	0.04	58.92	–0.13	–0.30
Hel	3.26	3.22	3.31	7.16	–0.85	–0.50

R and test procedure has confirmed the significance of the results RLQ-analysis at the p-level of 0.01. Axis RLQ – it is integral estimates interrelation between environmental factors (Kunakh *et al.*, 2013). In this case, we take into account the structure, hardness, conductivity and temperature of the soil as well as of vegetation structure using physiognomic types Phytoindication scale by Tsyganov and ecomorphes structures according to Belegarde. Axis RLQ-analysis –is the integrated assessment of interrelation of two matrices: the first shows the sampling points (spatial component, taking into account the fact that the coordinates of sampling points were recorded), the second - the location types of the soil mesofauna, and the third - the significance level of environmental factors and the level of significance of ecomorphes characteristics of mesofauna (Figure 2). Environmental factors which structure the community, have a complicated integral nature and reflected through measurable characteristics. Complexes related characteristics in multivariate techniques allocate according to various criteria, since the number of factor solutions is infinite. Maximize described dispersion and correlation factors are the target criteria in multivariate factor analysis and principal component analysis. It is obvious that such criterion has a general character and does not reflect the specificity of environmental problems. Maximization of criterion in RLQ-analysis is the solution which best describes relationship between different environmental phenomena - the environment, the community and its formal environmental properties (*Kunakhet al*., 2013).

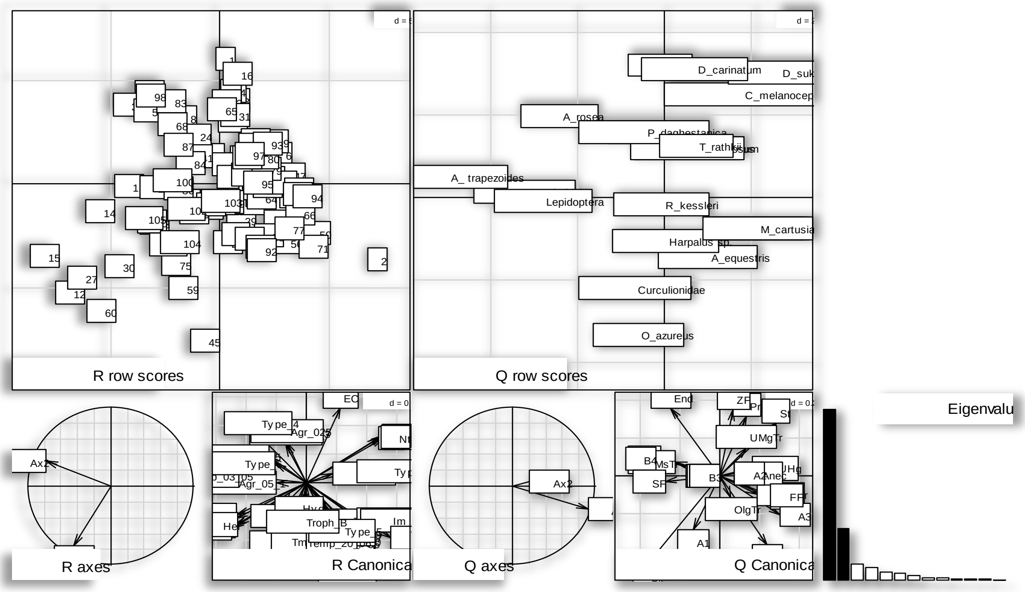

Figure 2 - The results of the analysis of RLQ. x-axis - RLQ-1 axis, y-axis - RLQ-axis 2; A - weight of sampling points (R-matrix) for RLQ-axes; B - weight species (Q-matrix) by RLQ-axes; C - correlation of principal components 1 and 2 are derived from factor analysis of environment variables and RLQ-axes; D - correlation of environment variables and RLQ-axes; E - correlation of principal components 1 and 2 are derived from factor analysis and ecomorphs RLQ-axes; F - correlation ecomorphs and RLQ-axes; G - histogram of eigenvalues.

Table 2. Analysis of the types of marginality communities of the mesofauna

Types	Reduction	Inertia	OMI	omi	tol	rtol	p-level
Amara equestris	A_equestris	52.1	7.1	13.7	9.9	76.4	0.04
Amphimallon solstitiale	A_solstitiale	24.7	9.4	38.1	0.8	61.1	0.35
Anoxia pilosa	A_pilosa	63.3	11.0	17.4	12.6	70.0	0.13
Aporrectodea rosea	A_rosea	43.9	1.5	3.5	25.2	71.3	0.00
Aporrectodea trapezoides	A_.trapezoides	49.1	1.9	4.0	23.2	72.7	0.00
Aranea sp.	Aranea	43.8	5.6	12.9	16.1	71.0	0.03
Brephulopsis cylindrica	B_cylindrica	41.3	0.1	0.2	10.0	89.9	0.54
Calathus melanocephalus	C_melanocephalus	48.8	6.7	13.9	5.7	80.4	0.33
Curculionidae sp.	Curculionidae	50.1	15.5	31.0	11.8	57.2	0.02
Dendarus punctatus	D_punctatus	77.9	23.0	29.6	9.9	60.5	0.01
Diphyonyx sukacevi	D_sukacevi	32.6	2.6	8.1	5.1	86.8	0.94
Dorcadion carinatum	D_carinatum	31.7	15.0	47.4	1.7	50.9	0.06
Harpalussp.	Harpalus.sp.	55.7	9.2	16.5	23.0	60.4	0.13
Helix lucorum	H_lucorum	43.3	0.7	1.8	7.8	90.4	0.46
Lepidoptera	Lepidoptera	50.4	14.0	27.8	12.2	60.0	0.08
Monacha cartusiana	M_cartusiana	39.9	0.2	0.6	14.7	84.7	0.06
Opatrum sabulosum	O_sabulosum	45.1	5.7	12.7	24.7	62.6	0.00
Ophonus azureus	O_azureus	30.4	8.9	29.4	11.4	59.3	0.56
Podonta daghestanica	P_daghestanica	35.9	4.1	11.6	25.4	63.0	0.24
Rossiulus kessleri	R_kessleri	42.2	0.7	1.6	10.30	88.1	0.65
Trachelipus rathkii	T_rathkii	26.9	3.2	11.9	7.0	81.1	0.67
OMI		6.9	–	–	–	–	0.00

Legend: OMI - index of the average distance (marginal) for each species; Tol - tolerance, Rtol - residual tolerance; italics index data presented in % of total variability; p-level using the Monte Carlo method after 25 iterations. The total inertia, which can be calculated as a result of OMI-analysis is proportional to the average marginality species community and is a quantitative assessment of the impact of environmental factors on the species separation (Kunakh *et al.,* 2013). Marginality - is the displacement degree of centroid ecological niche of the species at typical conditions represented by a polygon.

The analysis revealed that the total inertia, which can be calculated in the analysis result of OMI,is proportional to the average marginality of community species and represents a quantitative assessment of the impact of environmental factors on the separation of species. The analysis determined that the total inertia is 1.99. The first axis, obtained from OMI-analysis describes 41.93%, and the second - 22.54% of inertia. So the first two axes describe 64.47% of inertia which is quite enough, in order to differentiate the description of ecological niches of mesofauna in the studied polygon in the space to carry out the first two axes. For the average value marginalized communities (OMI = 6.99) the significance level is p = 0.00, which indicates the importance of the selected environment variables for the structuring of the soil mesofauna community. The marginalitywhich was significantly different from the random alternatives characteristic of 3 types out of 21, for which carried out the OMI-analysis (Table 3). Thus, for most species of the studied landfill typically edaphic conditions are identical with the centroid of their ecological niche.

Configuration of ecological niches is presented in Figure 3.

RLQ-analysis allows us to classify animals according to the nature of their ecological structure and due to environmental factors. The cluster analysis allowed identifying four complexes species that form the functional groups A, B, C and D (Figure 4).

The location of these functional groups in space RLQ axes are shown in Figure 5. A functional group includes most consists of xerophilic steppe species (eg O. azureus, A. equestris, R. kessleri).

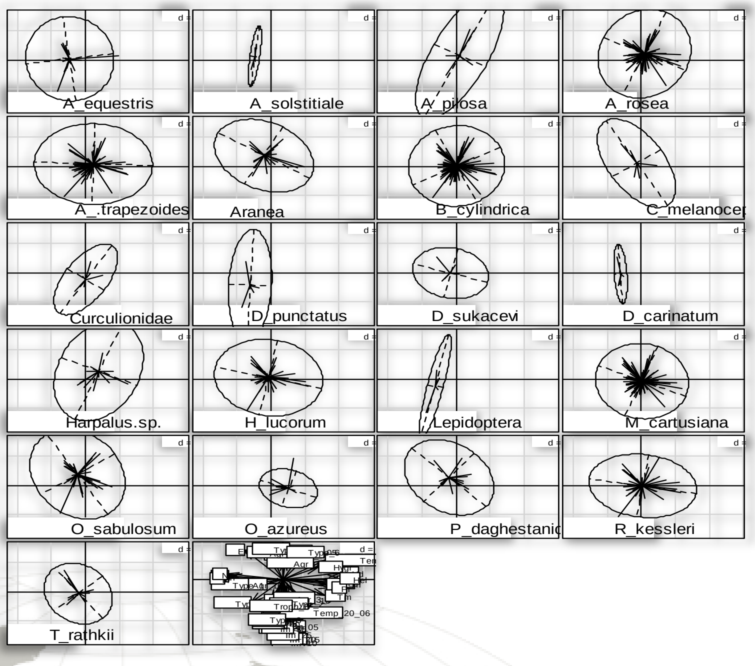

Figure 3 -The ecological niches of species of soil macrofauna

Legend: The coordinate axes are specified with components of marginality; origin - zero marginal. The ellipse represents the inertia of ecological niche. Rays associated with the centroid ecological niche sites meeting the form in the space of marginalized communities. In the lower right corner of the normalized weight of environmental

This functional group is sensitive to the vertical differentiation of the soil profile (marker - axis 2). The functional group is represented in xerophilic steppe species (Lepidoptera sp. Larvae), mesophilic steppe species (A. rosea), hygrophilic meadow species (A. trapezoides) and hygrophilic forest species (A. solstitiale). The main axis is determined by the appearance of communities 1. The third functional group C is mainly composed of xerophilicStepanov (egOpatrumsabulosum, Podontadaghestanica). Group C is sensitive to vertical differentiation of the soil profile (marker - axis 2). The fourth functional group D are terrestrial snails (Mollusca, Gastropoda), which hygromorphes and coenomorphes aspects are mesophilic. Group D is sensitive to the 1 axis.

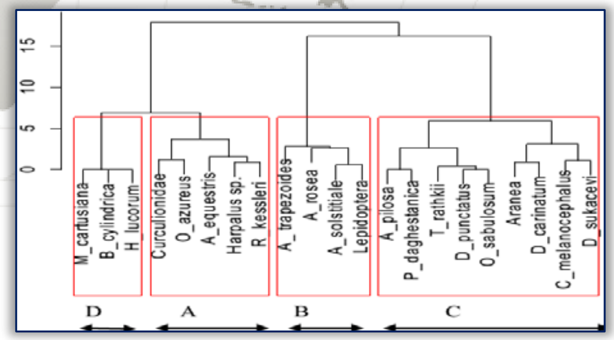

Figure 4- The cluster analysis of the structure of the animal population of the soil

Ecological specialization is the adaptation of an organism or group of organisms to the narrow conditions of existence. Ecological specialization within the context of concrete conditions takes the form of functional groups. Ecomorphs structure analysis of the animal population allows determining the nature of the functional groups obtained in terms of the provisions of this habitat (Figure 5). An important tool for describing the ecological structure of the animal population is its reflection in geographic space. Spatial variability RLQ-axis is shown in Figure 6.

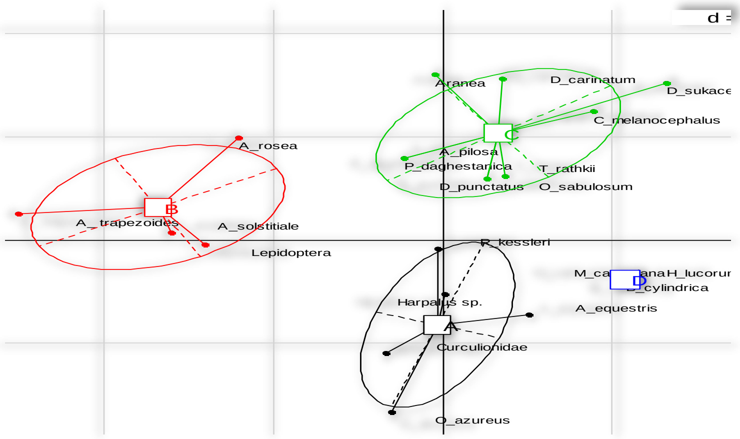

Figure 5 - Location of the functional groups in the space of RLQ-axes

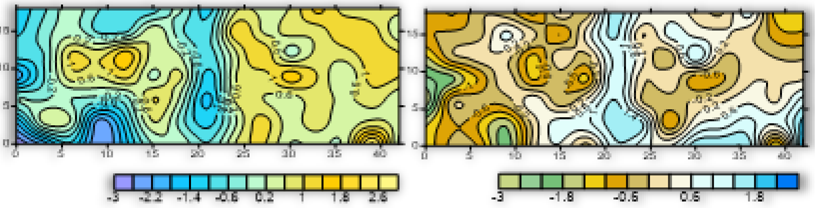
Figure 6 - Spatial variability RLQ-axes

Figure 6 shows the trends of relatively independent of the spatial variability of the animal population of soddy-lithogenic soils on loessial sandy loams. Figure 6 demonstrates the spatial distribution of soil animals relative to the axis 1: the high values indicate a high density of functional groups of representatives, on the other hand, the low values - functional group B. The functional group A is relatively tolerant to the axis 1.

Figure 6illustrates the spatial distribution of soil animals relative to the axis 2. The area with a high density of representatives of functional groups B and C are fragmentary and alternated with areas where there is a high density of members of the group A.

4. CONCLUSIONS

According to the analysis and interpretation of results obtained in the present research the following points should be emphasized:

- It is established that edaphic characteristics sod-lithogenic soils on loessial sandy loams and vegetation cover characteristics (ecomorphs and using phytoindication scale) describe the 87.71% of the variation spatial distribution of soil animals.
- Using the RLQ-analysis, the two axes of differentiation of animal populations that are integral evaluation of the entire set of environmental factors. Axis 1 describes 62.81%, and the axis 2 - 18.90% of spatial variability distribution of mesofauna.
- Was noted statistically significant marginality of 3 species (O. sabulosum, A. rosea, A. trapezoides) of 21, which indicates non-random choice of habitat preference of these types of specific conditions for life.
- The functional groups of soil animals derived by using cluster analysis on the basis of interrelation ecomorphs structure and environmental factors that reflect the differentiation of ecological niches of individual groups of species which are sensitive to hardness of, soil temperature and projective cover plants.
- The mapping axes RLQ-analysis in geographic space shows that the study polygon is not uniform for soil anmal.

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