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Ecological features of transitional soils landscape zones of Western Siberia

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Abstract. **The basis** of an information resource that answers all scientific and practical requests is the knowledge of nature-forming factors, ecosystems with their distribution patterns and ecological functions. The phenomena of landscape cover zoning are of theoretical and applied interest in connection with the development of modern farming and irrigation systems. **The purpose of the research is** to assess the soils of the transitional landscape zones of Western Siberia. **Research methods.** A complex of field and laboratory research methods was used. The objects of study are the soils of the Karasuk plain. **Results.** The problem of natural and anthropogenic extremeness of ecological conditions in Western Siberia is considered. Transitional landscapes on the border of natural zones are characterized by climate instability, variegated soil and vegetation cover. A unique diversity in combinations and complexes of soil cover and biogeocenoses is shown, which must be reflected in the development of ecological and geological certification of natural systems. The features of the soil cover with pulsating moisture and bioindication of its ecological situation have been studied. Fertile soils that can be used in irrigated agriculture are represented by southern black soils the reclamation characteristics of which show that they should be irrigated with norms that exclude unproductive losses of irrigation water due to filtration. When irrigating them, the specific properties of intrazonal soils should be taken into account. The peculiarities of the properties of the studied soils of the transitional landscape zones determine the dynamics of the dispersal of shell mites in them, as an indicator of the ecological situation of the soil cover. **Scientific novelty.** An assessment of the natural and anthropogenic extremality of the ecological conditions of Western Siberia as an information resource for rational nature management in conditions of climate change is given. The instability of climatic indicators with poor drainage of the territory and limiting moisture is determined by modern environmental conditions.

Keywords: landscape areas, environmental management, soil, chernozem, irrigation, bioindication, biogeocenosis, microarthropods.

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Introduction

Transitional landscape zones on the border of zones with climate instability, variegation of soil and vegetation cover, and increased species diversity of flora and fauna attract attention when discussing the issues of soil cover zoning and its rational use under conditions of increased anthropogenic pressure and climate change [1; 2]. The transition zone between the forest-steppe and steppe landscape zones in Western Siberia is a typical example of natural and anthropogenic extreme environmental conditions (fig. 1).

A typical area of the Kulunda plain is the Karasuk low ridge plain, which is determined not only by its intermediate position in the north-south row of landscape zones, but also by its location in the middle part of the continentality gradient along the Voeikov baric axis. This territory is characterized by an increase in moisture, a decrease in the continentality of the climate. Poor drainage in the south of the West Siberian Plain and limiting moisture determine the diversity of saline soils, which enhances the extreme nature of environmental conditions. The problem of nature management of such territories under the conditions of climate change concerns both theoretical and applied aspects [3–5].

The flat relief of the Karasuk plain is characterized by an ecological regime that provides a unique diversity and combination of soils and biogeocenoses [6].

Various studies of this natural object were carried out by the Institute of Animal Systematics and Ecology of the Siberian Branch of the Russian Academy of Sciences, the Institute of Soil Science and Agrochemistry of the Siberian Branch of the Russian Academy of Sciences, Altai State University, etc. [7–11].

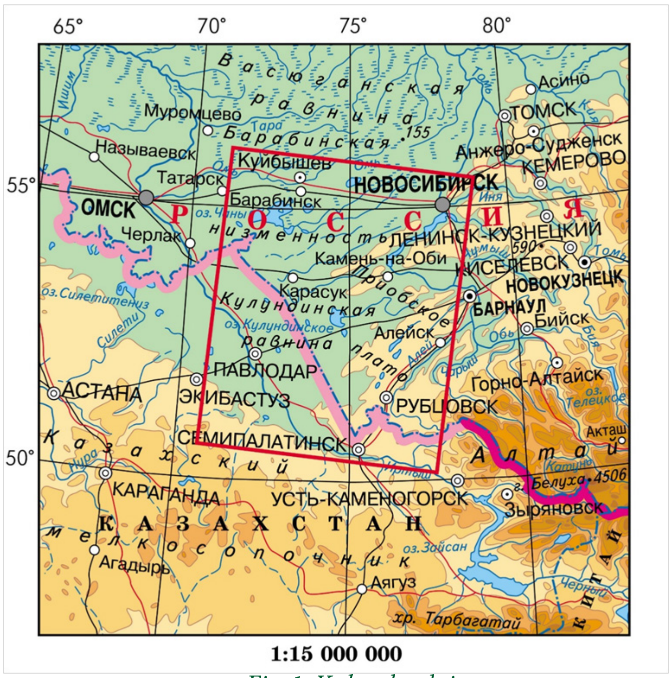

Fig. 1. Kulunda plain

At present, scientific and practical interest in similar territories is also associated with the development of ecological and geological certification of natural systems, which takes into account the biological and geological features of the territories as a complex mechanism for rational nature management [12].

The purpose of the research is to give an ecological assessment of the zonal and intrazonal soils of the transitional landscape zones of Western Siberia. The study of the features of the soil cover with pulsating moisture and bioindication of its ecological situation is the task of this study.

Methods

The objects of study were the soils of the Karasuk plain within the terraces of the lakes Krotovaya Lyaga, Maloye Chernoye, Astrodym (salty), the basin of the river Karasuk.

There were used field and cameral methods. The sections were laid down to a depth of 100 cm. The analyzes of soil samples from each horizon were performed according to generally accepted methods. Vegetation is described in the places where soil sections are laid.

Bioindication is the most accessible method for diagnosing the natural environment. Microarthropods, which are very sensitive to the moisture regime, can serve as indicators of environmental conditions during climate change – animals represented by shell mites up to 1 mm in size and living in soil pores [11; 13–16]. The population of armored mites was studied by bioindication using a frame 10 × 10 cm in size. The number of microarthroprods is calculated per 1 m^2.

Results

Soils, as the most conservative component of biogeocenosis, respond to special conditions of pulsating moisture not so much with the dynamics of their properties, but with an increased diversity of taxa in space. In the Karasuk district of the Novosibirsk region, where the research was carried out, more than 50 % of the land is occupied by a very variegated alkali soil-salt marsh complex. On the positive elements of the relief – manes and flat ridges – southern black soils (zonal soils of real prairies) are common, which make up 27.5 % of the total area. Black soils can be used for irrigated agriculture. The basis for melioration is the local water resources of small rivers, fresh lakes, groundwater. However, irregular irrigation leads to environmental risks in soil-forming processes, water and air regimes, and changes in the reclamation properties of soils. Secondary salinization, hydromorphism phenomena and other degradation of black soils occur [8; 10; 18; 19].

Morphological description of the southern basin of the river Karasuk's black soil is next.

Top of the mane, sowing wheat.

$A_{пах}$ 0–20 cm. Dark gray with a brownish tint, light loamy, lumpy-silty, slightly compacted, densely permeated with plant roots, the transition to the AB horizon is very gradual.

AB 20–50 cm. Brownish-gray, with gray tongued streaks of humic substances, light loamy, lumpy, compacted, permeated with plant roots, gradual transition to horizon B_1.

B_1 50–70 cm. Heterogeneously colored, brown, with humus streaks, sandy loamy, compacted, permeated with plant roots, the transition to the B_{2k} horizon is noticeable.

$B_{2к}$ 70–90 cm. Light brown, with whitish spots of carbonates, light loamy, dense, slightly penetrated by roots, effervesces from HC_1, noticeable transition.

$BC_к$ 90–140 cm. Brownish-yellow, loosely lumpy, sandy loamy, slightly compacted, plant roots are rare,

Table 1

Particle size distribution of the Southern black soil

Depth, cm	Hygroscopic moisture, %	Number of particles with diameter (mm), %						
		1.0–0.25	0.25–0.05	0.05–0.01	0.01–0.005	0.005–0.001	< 0.01	< 0.001
Virgin land								
0–10	1.72	3.7	58.9	9.4	2.6	5.1	19.3	27.0
10–20	1.57	11.5	52.4	9.1	3.4	5.9	17.0	26.3
20–30	1.60	13.4	51.8	7.8	3.6	4.3	18.3	26.2
30–40	1.89	14.1	47.6	8.4	3.5	4.6	21.2	29.3
40–50	1.56	16.6	48.2	9.2	1.6	3.6	18.5	23.7
Arable land								
0–10	1.60	24.8	45.1	5.6	1.4	6.3	16.0	23.7
10–20	1.54	18.0	44.2	11.9	2.8	3.8	18.2	24.8
20–30	1.78	24.2	41.5	7.4	6.6	2.3	18.4	27.3
30–40	1.61	23.7	47.1	5.6	1.2	5.8	16.3	23.3
40–50	1.39	25.2	47.5	6.4	0.8	4.4	15.2	20.4

Table 2

The composition of the aqueous extract of southern black soil

Horizon	Depth, cm	Dense remainder, %	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	$Na^{+}+K^{+}$	pLMC
			meq / 100 g dry soil						
A_{arable}	0–20	0.10	0.70	0.14	0.41	0.21	0.21	0.83	6.9
B_1	20–50	0.08	0.44	0.14	0.23	0.15	0.15	0.71	7.8
B_2	50–70	0.10	0.80	0.12	0.67	0.27	0.19	1.13	8.2
Carbonate	70–90	0.11	0.52	0.15	1.54	0.20	0.20	0.81	8.4
Transitional carbonate	90–140	0.09	0.46	0.20	0.73	0.20	0.28	0.91	8.7
Mother breed	140–200	0.10	0.84	0.32	0.34	0.17	0.19	1.14	9.2

carbonates are found in the form of spots and pseudomicellar segregations, the transition to horizon C is clear.

$C_к$ 140–200 cm. Light brown, loosely lumpy, compacted, sandy-loamy loamy, effervescent.

The profile of southern black soils in the upper part, as a rule, has a light loamy granulometric composition, and in the lower part – sandy loamy, with rare interlayers of light loams and sands (table 1).

The granulometric composition of these soils is characterized by the absolute predominance of sandy fractions 1.0–0.25 and 0.25–0.50 mm in size, making up to 65–77 of all particles, which ensures good natural drainage of the soil stratum. The smallest number of particles falls on medium dust (particles with a size of 0.01–0.005 mm).

When comparing the granulometric composition of virgin and arable black soils, it can be seen that the black soil in the arable land, especially in the upper layers, is depleted in silt particles, and in the 0–10 cm layer, as a result of more intensive manifestation of wind erosion processes on the arable land, it is depleted in silty particles.

Evaporation from HCl is noted in individual wedges from 57 cm, the maximum accumulation of carbonates in the B2K horizon. Groundwater is located at a depth of 5–8 m, their capillary fringe, due to the light granulometric composition of soil-forming rocks, is only 80–100 cm, so they do not participate in modern soil-forming processes, which is a prerequisite for successful irrigated agriculture on the studied black soils. The reaction of the medium in the upper horizons is neutral (pH_b = 6.9), in carbonate – alkaline (pH_b = 8.2–9.2). Black soils are not saline with readily soluble salts (table 2).

The dense residue throughout the profile does not exceed 0.11 %.

The content of humus in the plow layer is 1.73 %, it gradually decreases down the profile and in the B_2 horizon decreases to 0.61 %. The low content of humus is due to the biological cycle of substances in an arid climate and the light granulometric composition of the soil.

Light granulometric composition and low humus content are the main factors that determine the physical and water properties of southern black soils (table 3).

These soils are characterized by high values of bulk density. Thus, in the arable layer the bulk density is 1.47 g/cm^3, while in the underlying horizons it still increases. When comparing the indicators on arable land and virgin lands, it can be seen that in the subsurface layer, the addition density reaches 1.61–1.67 g/cm^3. On the virgin soil at this depth, the density index is much lower (1.49–1.51 g/cm^3). This caused a difference in the total porosity and porosity of soil aeration at the lowest moisture capacity (LMC): this indicator on virgin soil in a layer of 0–50 cm is 21.1 %, on arable land 18.5 %

of the soil volume. The density of the solid phase increases down the profile in line with the decrease in organic matter content.

The low content of humus and fine particles determines the weak hydrosorption capacity of light loamy southern black soils. The maximum hygroscopicity (MH) on arable land and virgin lands has similar values: in the layer of 0–50 cm – 4.4–4.9 % of the soil mass, and in the underlying layers of a lighter mechanical composition – 2.3–2.4 %. The humidity of stable wilting (SW) changes similarly: from 5.8–6.4% in the 0–50 cm layer to 3.0–3.1 % of the mass of dry soil in the underlying layers.

Studies have also shown that southern light loamy black soils have low water-retaining capacity. The lowest moisture capacity (HB) is established on the 5th day after abundant moisture and is 16.1 % on arable land in the 0–50 cm layer, and 13.4 % in the 0–100 cm layer. On virgin lands, HB is uniform throughout the profile (15.8 %). Moisture reserves at HB on arable land in a layer of 0–50 cm are 111.7 mm, and in a layer of 0–100 cm – 205.2 mm, on virgin soil, respectively, 117 and 234 mm.

At the same time, it is characteristic that, under natural conditions, the moisture content of light loamy southern black soils does not reach the HB value even in spring. This indicates the need for irrigation of these soils; at the same time, their weakly holding capacity does not give grounds for carrying out irrigation at high rates, which can cause water erosion, secondary salinization, and hydromorphism.

Despite the low moisture capacity, the active moisture range (AMR) in these soils is quite wide: 12.3 % on arable land and 10.5–8.1 % of the mass of soil on virgin soil in the 0–50 cm layer. Moisture reserves equal to AMR in the layer 0–100 cm, are 116 mm (61 % HB).

Features of the granulometric composition, the structure of the pore space and the weak water-retaining capacity of southern light loamy black soils determine their increased water permeability and filtration, which are 154 in the 1st, 2nd and 3rd hours, respectively; 128 and 123 mm on arable land and 245; 214 and 150 mm under natural steppe vegetation (table 4).

The duration of soaking on virgin soil is much longer than on arable land, which is probably due to the formation of a compacted subsurface layer.

The growth of both cultivated and natural vegetation depends not only on the downward movement of moisture and its accumulation in the soil profile, but also on the ability of stored moisture to move from the lower soil layers to the upper ones, which are most involved in the nutrition of plant roots. Experiments with chlorine-labeled water on southern light loamy black soil showed that after wetting the profile of this soil to the state of HB, the upward movement of moisture in liquid form occurs only in a layer of 0–30 cm on the 1st

Table 3

Physical and water properties of southern black soil

Depth, cm	Soil density, g/cm^3		Porosity, %		Lowest moisture capacity	Maximum hygroscopicity	Wilting moisture	Active moisture range
	Additions	Solid phase	General	Aeration	% of soil mass			
Virgin land								
0–10	1.42	2.65	46.4	20.8	18.0	5.8	7.5	10.5
10–20	1.51	2.62	42.4	17.7	16.4	4.6	6.0	10.4
20–30	1.49	2.69	44.6	20.9	15.9	4.6	6.0	9.9
30–40	1.51	2.70	44.1	21.5	15.0	5.3	6.9	8.1
40–50	1.49	2.69	44.6	24.5	13.9	4.5	5.8	8.1
60–70	1.49	2.70	44.8	23.8	14.1	5.1	6.6	7.5
70–80	1.55	2.70	42.6	20.1	14.5	4.1	5.3	9.2
80–90	1.60	2.70	40.7	18.6	14.2	4.3	5.6	8.6
90–100	1.63	2.70	39.6	13.7	15.9	2.9	3.8	12.1
Arable land								
0–10	1.40	2.59	55.0	29.1	18.5	6.7	6.2	12.3
10–20	1.54	2.60	40.7	13.1	17.9	7.5	6.4	11.5
20–30	1.61	2.62	40.0	16.8	14.4	8.0	6.5	7.9
30–40	1.67	2.63	36.5	15.1	12.8	6.7	5.3	7.5
40–50	1.65	2.65	37.7	18.2	11.9	5.8	4.6	7.3
50–60	1.48	2.61	43.2	25.6	11.9	5.2	4.6	7.3
60–70	1.51	2.64	42.8	24.4	12.2	10.3	8.8	3.4
70–80	1.60	2.67	40.1	19.5	12.9	8.8	7.2	5.7
80–90	1.64	2.64	37.9	16.6	13.0	6.1	4.8	8.2
90–100	1.6	2.64	39.4	25.8	8.5	3.7	3.0	5.3

day of evaporation. In the following days, the evaporative consumption of moisture from the soil is carried out by intrasoil evaporation and paradiffuse movement of moisture, which is provided due to the physical properties of the soil discussed above.

The amount of moisture moving to the surface from the lower layers in the form of steam does not make up for its deficit in the active soil layer. In addition, part of the vapor-forming moisture migrates to deeper, less warm layers. Therefore, due to the peculiarities of the water regime of southern light loamy black soils, their irrigation should be carried out in accordance with the norms that exclude unproductive losses of irrigation water due to filtration.

In the soil cover of the river basin. In Karasuk, along with southern black soils, soils of the intrazonal series are also widely developed – meadow-black soil, alkali soils and salt marches. They are located on slopes and in depressions in concentric belts around lakes.

The highest areas from the lake are occupied by meadow-black soils, usually alkaline.

Here is a morphological description of the meadow-black soil.

Lake terrace Krotovaya Lyaga, lower part of mane with northern exposure, pasture. Vegetation: fescue, licorice, thyme, plantain.

A 0–2 cm. Sod.

A 2–20 cm. Dark gray, lumpy, dry, slightly compacted, densely permeated with plant roots, gradual transition.

AB 20–43 cm. Brownish-gray, with humus streaks, lumpy-nutty, dry, compacted, many roots, gradual transition.

B_1 43–56 cm. Brown, with gray streaks of humic substances, nutty, dense, gloss along the edges of structural units, fewer roots than in the AB horizon, gradual transition.

B_2 56–75 cm. Brown, with slight streaks of humic substances, dense, the transition is noticeable in color.

BC_{1K} 75–100 cm. Brownish-whitish, finely nutty, dense, many plant roots, effervescent from HC1, the transition is noticeable in color and density.

Table 4

Water permeability of light loamy southern black soils

Section, land	*Absorption time 100 mm, min*	*Water permeability from the surface, mm*		
		1st hour	*2nd hour*	*3rd hour*
R-3, arable land	*45*	*154*	*128*	*123*
R-2, virgin land	*30*	*245*	*214*	*150*

Table 5

Granulometric composition of meadow black soil (pasture)

Depth, cm	*Hygroscopic moisture,%*	*Number of particles with diameter (mm), %*						
		1.0–0.25	*0.25–0.05*	*0.05–0.01*	*0.01–0.005*	*0.005–0.001*	*< 0.01*	*< 0.001*
0–20	*2.48*	*8.2*	*33.9*	*18.2*	*6.3*	*9.2*	*22.4*	*37.9*
20–43	*1.92*	*13.2*	*35.5*	*13.8*	*4.6*	*7.8*	*24.2*	*36.6*
43–56	*1.76*	*11.2*	*44.4*	*12.3*	*4.4*	*3.8*	*23.2*	*31.4*
56–75	*1.67*	*13.3*	*47.4*	*10.8*	*3.9*	*3.5*	*20.6*	*28.0*
75–100	*2.11*	*9.2*	*34.7*	*17.0*	*3.0*	*4.3*	*23.4*	*30.7*
100–120	*2.66*	*2.6*	*10.4*	*17.6*	*8.6*	*12.7*	*28.0*	*49.3*
130–140	*2.68*	*2.4*	*11.1*	*17.7*	*7.7*	*12.8*	*31.2*	*51.7*
170–180	*2.50*	*4.2*	*21.1*	*19.9*	*5.5*	*8.7*	*29.2*	*43.4*
200–210	*2.50*	*4.5*	*21.0*	*21.5*	*4.7*	*13.0*	*25.4*	*43.1*

Table 6

Water-physical properties of meadow black alkali soil

Depth, cm	*Soil density, g/cm³*		*Porosity, %*		*Lowest moisture capacity*	*Maximum hygroscopicity*	*Wilting moisture*	*Active moisture range*
	Additions	*Solid phase*	*General*	*Aeration*	*% of soil mass*			
0–20	*1.25*	*2.59*	*51.7*	*28.0*	*19.0*	*7.7*	*9.9*	*9.1*
20–43	*1.43*	*2.66*	*46.2*	*24.3*	*15.3*	*6.6*	*8.6*	*6.6*
43–56	*1.51*	*2.69*	*43.9*	*25.2*	*12.4*	*6.0*	*7.8*	*4.6*
56–75	*1.57*	*2.67*	*41.2*	*21.4*	*12.6*	*5.9*	*7.7*	*4.9*
75–100	*1.62*	*2.68*	*39.6*	*23.1*	*10.2*	*6.2*	*8.1*	*2.1*
100–120	*1.57*	*2.72*	*43.2*	*24.7*	*11.2*	*8.4*	*10.9*	*0.3*
120–180	*1.71*	*2.73*	*37.4*	*18.4*	*11.1*	*8.0*	*10.4*	*0.7*
180–210	*1.70*	*2.71*	*37.3*	*18.4*	*11.1*	*8.0*	*10.4*	*0.7*

C_{1K} 100–120 cm. Brown, finely nutty, slightly compacted, moist, effervescent, carbonates in the form of a white-eye, few roots, the transition is noticeable in color.

C_2 120–230 cm. Brown, finely nutty, slightly compacted, moist, wet at the bottom, effervescent from HCl, carbonates are scattered.

The granulometric composition of the meadow-black soil is medium loamy, in the deep layers it is heavy loamy (table 5).

The soil profile is noticeably differentiated both in terms of the amount of silt particles (< 0.001 mm) and the content of physical clay (< 0.01 mm). In the upper parts of the meadow black soil soil, as in zonal soils (southern black soil), the fine sand fraction (0.25–0.50 mm) predominates, in the deep layers of the soil – the silt fraction, and fine sand and coarse dust are also noticeably represented. (0.05–0.01 mm).

The bulk density in horizon A is 1.25 g/cm^3, in horizon B the bulk density increases to 1.57, and in horizon C to 1.70 g/cm^3 (table 6). The last two values indicate salinization of the profile of this soil.

The density of the solid phase in the upper soil horizons is 2.59 g/cm^3, gradually increasing with depth up to 2.71–2.73 g/cm^3. The total porosity varies from 51.7 in horizon A to 37 % of the soil volume in horizon C, from satisfactory in terms of agro-reclamation to low values, which indicates insufficient soil aeration.

The porosity of aeration at the lowest moisture capacity in the upper 50 cm layer, the most enriched with roots, is on average 20 % of the soil volume, in the layer of 50–100 cm 23 %, and in the parent rock – 18 % of the soil volume.

The water-physical properties of the meadow-black soil are characterized by increased moisture values compared to the southern black soils, corresponding to the maximum hygroscopicity (MH) of the soil, especially in the humus horizon, which is explained by its enrichment with organic matter.

HB meadow-black soil is low, and AMR is satisfactory (44–48 % HB) only in horizon A. In general, the AMR of the meadow-black soil is significantly lower than in the black soils that are distributed higher in relief.

In the humus horizon, MH makes up 6.6–7.6 % of the soil mass (40–43 % HB), in the middle part of the profile – about 6 %, and in the parent rock, more enriched in silt particles – 8 %.

SW in the humus horizon is 8.6–9.9 % of the soil mass (52–56 % HB), in horizon B – 8 %, or 62 % HB, in the soil-forming rock the amount of moisture inaccessible to plants increases to 94 % HB, and the AMR is only 6 % HB (table 6).

Water permeability of meadow-black soils is satisfactory. On the pasture from the surface, it was 176 mm for the 1st hour, 110 – for the 2nd hour and 82 for the 3rd hour.

Meadow-black soils are characterized by a significant accumulation of humus (up to 6–9 %) and its gradual decrease down the soil profile. This is facilitated by the abundance of herbaceous vegetation, increased moisture content of the soil profile due to closely spaced groundwater, and a rich world of microorganisms. Meadow-black soils have a high exchange capacity, which in the upper horizon is 40–50 meq/100 g of soil.

The exchange bases are dominated by Ca^{2+} and $Mg^{2+;}$ absorbed Ca^{+} is up to 8 % of the exchange capacity, depending on the degree of soil alcalinization.

Ground waters here are at a depth of 2.3–2.5 m from the soil surface, they are highly mineralized (table 7) and, if they occur close to each other, have an impact on soil-forming processes. At present, the upper part of the meadow-black soil profile is practically not saline.

Water-soluble salts are present in small amounts – 0.06 %, pH_b is 6.9. However, groundwater is highly saline with chloride salts, which should be taken into account when using these soils, in particular for irrigation. Shallow highly saline groundwater can quickly saline the surface horizons of the soil.

The considered meadow-black soils are currently used as pastures. Considering that they are found in the river basin. Karasuk is usually combined with saline soils; this method of using meadow black soils is obviously the most expedient.

At the same time, it should be taken into account that excessively high knocking out of the vegetation cover by animals should not be allowed, otherwise the rise of highly mineralized groundwater and salinization of the upper soil layers may occur. The features of meadow black soils discussed above should be taken into account when irrigating them. It should be carried out under strictly observed scientifically based regimes.

The strip of meadow-black soils is replaced towards the lake by a concentric belt of alkali soils. At the beginning there is a belt of alkali soils with individual patches of salt marchs. Salt licks are diverse in generic and species composition, and similar in morphological features.

Below is a morphological description of the most common meadow-steppe alkali soils here.

The slope of the mane, 100 m southeast of the lake. Black. Pasture.

AO 0–1 cm. Sod.

A 1–11 cm. Dark gray, light loam, cloddy-silty, dense, dry, weak silica powder, permeated with plant roots, noticeable transition.

B_1 11–35 cm. Dark gray, coarsely cloddy-prismatic, very dense, fissured, dry, roots in structural units, the transition is noticeable in structure and density.

B_2 35–70 cm. Brown, with dark streaks of humic substances, nutty-prismatic, compacted, luster according to structural units, gradual transition.

BC 70–110 cm. Heterogeneously colored, brown, with rare humus tongues, loosely lumpy-prismatic, rarely plant roots, moist, noticeable transition.

C_{1K} 110–150 cm. Brownish-whitish, prismatic-lumpy, carbonates violently effervesce from HC1 in the form of veins, spots, moist, gradual transition.

Table 7

Salinization of soils, ground waters and waters of the lakes of the Karasuk water system

Place position	The soil, water	pLMC	Solid residue, %	Mineralization of water, g/l	Salinization	
					Degree	Type
Lake Krotovaya Lyaga, terrace	Meadow black alcali easily loamy	6.9	0.0580	–	Non-salted	Sulfate soda
	Groundwater	7.8	–	27.6	Strongly mineralized	Chloride
Lake Maloe Chernoe, terrace	Salt lick meadow medium loamy	7.4	0.0200	–	Non-salted	Chloride
	Groundwater	7.9	–	2.7	Slightly mineralized	Chloride
Lake Krotovaya Lyaga, terrace	Salt lick meadow medium loamy	7.9	0.678	–	Average salted	Chloride-sulfate
Lake Astrodym (salty), terrace	Typical salt marsh meadow medium loamy	8.0	3.672	–	Saline	Chloride
	Groundwater	7.4	–	75.0	Brines	Sulfate chloride
Lake Maloe Chernoe, terrace	Typical salt marsh meadow medium loamy	7.3	4.894	–	Saline	Chloride
Lake Krotovaya Lyaga, terrace	Typical salt marsh meadow medium loamy	7.5	3.500	–	Saline	Sulfate
	Groundwater	8.0	–	8.3	Average mineralized	Sulfate
Lake Astrodym (salty)	Water	7.1	–	26.3	Highly mineralized	Sulfate soda
Lake Maloe Chernoe	Water	7.3	–	10.1	Highly mineralized	Chloride-sulfate
Lake Krotovaya Lyaga, terrace	Water	8.0	–	0.5	Fresh	Sulfate soda

C_{2K} 150–260 cm. Brown, loosely lumpy-prismatic, moderately compacted, moist, wet below.

The groundwater level is at a depth of 2.5 m and salinized to varying degrees. The type of salinity is chloride and sulfate. The reaction of the alkali soil environment is alkaline (table 7).

The type and degree of salinity of alkali soils influence the formation of vegetation in the lake basin: the less salts, the more often fescue occurs along with wormwood and other salt-tolerant plants. So, on the steppe meadow alkali soil, almost non-saline (dense residue 0.02 %), wormwood and fescue grow, and on the meadow alkali soils with an average degree of salinity with chloride-sulfate salts (dense residue 0.678 %), fescue is replaced by a more salt-tolerant plant, the fescue.

The considered alkali soil has a light loamy-sandy loamy granulometric composition (table 8).

A feature of these alkali soils is the unexpressed differentiation of the soil profile in terms of the content of silt particles and physical clay, which is explained by the predominance of fine sandy fraction (particles 0.25–0.50 mm in size) in it, constituting from 50 to 70 % of all particles.

The parent rocks are layered, sandy-loamy, carbonate. The light granulometric composition determines the good natural drainage of these soils.

The volumetric mass of the alcali soil is increased even in the above alcali horizon (A) (1.42 g/cm^3 (table 9). This is explained not only by the lighter granulometric composition of the soil, but also by some of its compaction as a result of the use of alcali soils as pastures.

The studied alkali soil is characterized by a high differentiation of the profile and density of composition.

The density of the solid phase varies from 2.58 g/cm^3 in the above alkali soil layer to 2.70 g/cm^3 in the lower part of the profile.

The total porosity in the above alkali soil horizon is satisfactory (45 % of the soil volume); in the subalcali horizon and in the parent rock, it decreases to 38–35 %. Correspondingly, the aeration porosity changes in the alkali soil profile at HB, which decreases from 21 % in the upper horizon to values that hinder aeration in the lower part of the soil profile (up to 12.5 % of the soil volume).

The studied light loamy sandy alkali soils are characterized by low values of MH and SW, constituting 3–4 and 4–5 % of the dry soil mass, respectively.

The HB of these soils is also directly dependent on the granulometric composition: 16 % in the upper horizons and 12–13 % of the mass of dry soil in deeper ones, which corresponds to 20–23 % of the soil volume

Table 8

Granulometric composition of alkali soil

Depth, cm	Hygroscopic moisture, %	Number of particles with diameter (mm), %						
		1.0–0.25	0.25–0.05	0.05–0.01	0.01–0.005	0.005–0.001	< 0.01	< 0.001
0–1	1.93	17.2	50.3	9.3	2.4	4.1	16.1	22.6
1–11	1.00	22.5	57.9	4.0	1.3	1.0	12.8	15.1
11–35	1.17	16.8	56.2	7.8	2.1	1.9	14.7	18.7
35–70	1.23	14.6	34.4	4.1	0.6	0.1	14.3	15.1
70–110	1.10	12.4	68.3	2.4	0.8	–	12.9	13.7
110–150	1.12	21.5	56.5	3.4	0.1	0.1	12.8	13.0
150–260	1.10	21.5	61.2	1.7	0.7	3.9	8.4	13.0

Table 9

Water-physical properties of meadow medium loamy alkali soil (pasture)

Depth, cm	Soil density, g/cm³		Porosity, %		Lowest moisture capacity	Maximum hygroscopicity	Wilting moisture	Active moisture range
	Additions	Solid phase	General	Aeration	% of soil mass			
1–11	1.42	2.58	44.9	21.4	16.6	3.0	3.9	12.7
11–35	1.46	2.66	45.1	21.7	16.0	3.3	4.3	11.7
35–70	1.66	2.69	38.3	16.7	13.0	4.0	5.2	10.8
70–110	1.67	2.69	37.9	17.4	12.3	3.9	5.1	7.2
110–150	1.63	2.70	39.6	17.4	13.6	3.2	4.1	9.5
150–260	1.74	2.68	35.1	12.5	13.0	3.0	3.9	9.1

(table 9). As a result, the moisture reserves at HB in the 50 cm layer are only 110 mm, in the 100 cm layer 219 mm. Such values of moisture reserves at HB are not typical for alkali soils of Siberia, they are usually much higher [2], which is explained by the light granulometric composition of this alkali soil and the poorly pronounced capillary inflow of groundwater moisture into the upper soil layers. However, the AMR of the alkali soil under consideration is not less than in alkali soil with a heavy granulometric composition: 12.7 % in the humus and 9.1 % of the soil mass in the C horizon, which corresponds to 76 mm in the 0–50 cm layer and 149 mm in the 0–100 layer. cm.

The water permeability of meadow-steppe alkali soils is quite high, which is explained by the features of its granulometric composition discussed above. In the pasture soil, water permeability from the surface was 95 mm for the 1st, 85 – 2nd and 84 mm for the 3rd hour.

The strip adjacent to the lakes is often occupied by salt marches with patches of alkali soils. The structure of salt marches, common around the lakes Krotovaya Lyaga, Maloe Chernoe, Astrodym (salty) are generally similar.

As an example of the morphological structure of the salt march, we present a description of the section laid out on the lower terrace of the lake. Astrodym (salty), in a depression, under a salty association.

A 0–10 cm. Dark gray, medium loamy, lumpy-prismatic, compacted, moist, salts in the form of pseudomycelium, there are other spots and plant roots, boils from hydrochloric acid, the transition to the next horizon is gradual.

B 10–20 cm. Bluish-dark brown, medium loamy, powdery, dense moist, salts in the form of pseudomycelium, with ocher spots and plant roots, gradual transition.

BC 20–30 cm. Bluish-brown, heavy loamy, finely nutty, very moist, salts, rusty spots, effervescent, gradual transition.

C_1 30–150 cm. Brown, heavy clay, finely nutty, dense, with bluish ocher spots, carbonates in the form of spots, boils violently from hydrochloric acid.

Groundwater in the studied salt marches is at a shallow depth – about 150 cm. They are highly mineralized – 26–75 g/l (table 7). This leads to a constant high moistening of the profile and the transfer of salts to the upper layers. The composition of salts is varied, the most frequent are chloride, sulfate-chloride, sulfate and chloride-sulfate types of salinization.

The type and degree of salinity strongly influence the nature of the vegetation cover. For example, in the case of a soda-free sulfate-chloride type of salinity, communities of sarzasan, saltwort, and quinoa develop. During the spring flood of the lakes, the transfer and redistribution of salts over the area are carried out. So, salt marches, directly adjacent to the lake. Astrodym (salty), whose water is sulfate-chloride with a mineralization of 26.3 g/l, have a chloride type of salinity, and those located higher up the slope - sulfate-chloride.

Salt marshes around the lake. Maloe Chernoe chloride-type salinity with a very high salt content – up to 4.89 %. The mineralization of water in the lake is 10.1 g/l, the type of salinity is chloride-sulfate. These data indicate an intensive process of soil salinization.

Lake Krotovaya Lyaga is fresh (0.5 g/l), the salt marches surrounding it have a sulfate type of salinity with a salt content of up to 3.5 %. During the spring flooding of salt marshes with lake waters, they are washed away from easily soluble salts, however, in dry periods, the capillary inflow of groundwater again brings salts into the upper layers of the soil. The salinity of groundwater here is 8.3 g/l, the type of salinity is sulfate.

Around the lake Krotovaya Lyaga is also quite common and alkali soil – salt marches, which have a markedly pronounced illuvial horizon, and the supra-alcali soil horizon is enriched with readily soluble salts that are toxic to plants, as a result of which vegetation is often almost completely absent on them. Soda, which is present in the lake and groundwater of nearby soils, takes part in the formation of these soils. All considered saline soils have an alkaline reaction (table 7).

Salt marshes are overcompacted, waterlogged, poorly aerated, most of the moisture in them is firmly bound and inaccessible to plants. Unsatisfactory physical properties, high salt content – all this leads to very low natural fertility and their use as unproductive pastures.

The peculiarities of the properties of the studied soils determine the distribution of armored mites in them. The distribution of shell mites along the soil profile depends on the humus content, plant roots and soil moisture. In the soils of the Karasuk plain, 155 species of oribatids were identified [20].

In the European part of Russia, 267 species are recorded, the habitat of which is described here mostly in the taiga-forest and tundra zones. The issues of migration of oribatid mites from soils not only to grasses as a result of the influence of environmental factors, but also to trees are considered [21].

The results of our studies of the soils of the Karasuk plain showed that the dynamics of armored mites along the profile is determined by the dynamics of soil moisture, which in turn depends on their physical properties and soil-hydrological parameters. In southern black soils on virgin lands and pastures, the species distribution of shell mites along the soil profile is different. On virgin lands, more than 80% falls on the surface layer of the soil (0–1 cm), with depth their number evenly decreases (table 10).

The plowing of southern black soils changes the species abundance of shell mites. Their number decreases both in the surface layer and with depth. Moreover, most of them are concentrated in the soil layer deeper than 15 cm, in which moisture is less dynamic.

Their distribution is similar in the meadow-black soil with well-developed sod under moderate grazing. However, the better water regime of these soils increases the species diversity and abundance of mites.

The vertical distribution depends on the density of the soil; therefore, the alkali soil's nature of the southern black soil prevents the dispersal of oribatids (table 10).

In the soils of the saline series with a weakly expressed sod, the dynamics of the species of armored mites is more pronounced than in the black soils, which is associated with the weak development of the sod and, as a result, the instability of the hydrothermal regime.

In alkali soils, the largest number of species is concentrated below the 0–1 cm layer.

Table 10

Distribution of shell mites in soils (June, 2018)

The soil	Humus horizon, cm	Sod and litter character	Soil density, g/cm^3	Usage	Total species	Speciesdeeper, cm		Number, thousand copies/m^2
						1	15	
Southern black, basin of the Karasuk river	20	Expressed	Poorly compacted	Virgin land	23	20	15	50
Southern black, basin of the Karasuk river		No	Poorly compacted	Arable land	17	9	14	30
Southern black earth, near lake Krotova Lyaga	38	Expressed	Compacted	Moderate grazing	19	15	10	34
Southern black, near lake Maloe Chernoe	20	Poorly expressed	Strongly compacted	Intensive grazing	16	13	9	18
Southern alcali black near lake Krotovaya Lyaga	25	Poorly expressed	Poorly compacted	Haymaking	20	11	9	45
Meadow-black near lake Krotovaya Lyaga	20	expressed	Compacted	moderate grazing	24	21	17	52
Alcali soil near lake Maloe Chernoe	11	Poorly expressed	Strongly compacted	Intensive grazing	12	5	5	15
Saline by the lake Astrodym (salty)	10	Fragmentarily	Poorly compacted	Not used	9	5	0	10

The constant waterlogging of salt marches, on the contrary, determines the concentration of shell mites in the upper layer.

Discussion and Conclusion

The Karasuk plain is characterized by a wide variety of soils. The southern black soils of light loamy granulometric composition have favorable agrophysical and reclamation properties and are currently all plowed. They are not saline, highly permeable, characterized by a wide range of active moisture and are a good object for irrigation, but irrigation rates should be small, excluding water loss for filtration beyond the root layer of the soil.

Meadow-black soils are medium loamy, characterized by increased sorption properties compared to southern black soils and, as a result, a significantly lower range of active moisture. The surface horizons of the meadow-black soil are not saline, but the groundwater is highly mineralized. Therefore, when irrigating them, scientifically based irrigation norms should be especially strictly observed in order to avoid secondary soil salinization.

Soils of the saline series (alkaline soils, salt marches), due to their unfavorable physical and chemical properties, are used as unproductive pastures. Ways to improve their productivity are associated with a number of appropriate reclamation techniques.

The ecological situation of soils can be diagnosed by the shell mites living in them. Moisture fluctuations in these soils cause the dynamics of shell mites along the profile even in an insignificant surface soil layer.

Thus, the basic principle of information support for rational nature management lies in the knowledge of natural objects represented by ecosystems with their ecological components, the patterns of their distribution, the characteristics of ecological functions and the main nature-forming factors, which together constitute an information resource that answers all scientific and practical requests.

References

1. Tokarev K. E., Rogachev A. F., Protsyuk M. P., Rudenko A. Y., Chernyavsky A. N., Tokareva Y. M. Analysis of promising methods of irrigation and melioration techniques of crops in arid climate // IOP Conference Series: Earth and Environmental Science. 2020. Vol. 488 (1). Article number 012047. DOI: 10.1088/1755-1315/488/1/012047.
2. Sen'kova L. A., Grinets L. V. Rol' edaficheskogo faktora i korneoborota v sovremennom rasteniyevodstve [The role of edaphic factor and root turnover in modern crop production] // Selektsiya i semenovodstvo v rasteniyevodstve: sbornik materialov mezhdunarodnoy nauchno-prakticheskoy konferentsii "Strategicheskiye zadachi po nauchno-tekhnologicheskomu razvitiyu APK". 2018. Pp. 282–296. (In Russian.)
3. Plutalova T. G. Geoekologicheskaya otsenka sostoyaniya i razvitiya sistemy zemlepol'zovaniya v usloviyakh transgranichnosti (na primere transgranichnoy territorii "Kulunda"): dis. … kand. geogr. nauk: 25.00.36 [Geoecological assessment of the state and development of the land use system in transboundary conditions (on the example of the transboundary territory "Kulunda"): dissertation … candidate of geographic sciences: 25.00.36]. Barnaul, 2018. 140 p. (In Russian.)
4. Senkova L., Grinets L., Vyatkina G., Tarbeeva D. Soil bank models for information support for the training of agrarian specialists // Advances in Intelligent Systems Research: Proceedings of the International Scientific and Practical Conference "Digitization of Agriculture – Development Strategy" (ISPC 2019). 2019. Pp. 168–173.
5. Tanasienko A. A., Chumbaev A. S., Yakutina O. P., Almendros G., Klenov V. Rainfall patterns associated with runoff and erosion levels in West-Siberian Black soils // Pochvy y и okrúżauśáa sreda. 2021. Vol. 4. No. 2. Pp. 53–67.
6. Belyayev V. I., Bondarovich A. A., Pon'kina E. V., Shcherbinin V. V., Shmidt G., Matsyura A. V., Kozhanov N. A., Rudev N. V. Temperaturnyy rezhim vozdukha i pochvy po dannym meteorologicheskoy i pochvenno-gidrologicheskoy monitoringovoy seti v Kulundinskoy ravnine za vegetatsionnyye periody 2013–2016 gg. [Temperature regime of air and soil according to the meteorological and soil-hydrological monitoring network in the Kulunda Plain for the growing seasons of 2013–2016 gg.] // Vestnik Altayskogo gosudarstvennogo agrarnogo universiteta. 2017. No. 3 (149). Pp. 30–37. (In Russian.)
7. Trofimova I. E., Balybina A. S. Rayonirovaniye Zapadno-Sibirskoy ravniny po termicheskomu rezhimu pochv [Zoning of the West Siberian Plain according to the thermal regime of soils] // Geografiya i prirodnyye resursy. 2015. No. 3. Pp. 27–38. (In Russian.)
8. Shmidt G., Bondarovich A. A., Shcherbinin V. V., Pon'kina E. V., Kharlamova N. F., Matsyura A. V., Shtefan E., Illiger P., Rudev N. V., Kozhanov N. A. Rezul'taty funktsionirovaniya mezhdunarodnoy agrometeorologicheskoy i pochvenno-gidrologicheskoy monitoringovoy seti v predelakh Kulundinskoy ravniny na yuge Zapadnoy Sibiri za 2013–2015 gg. [Results of the functioning of the international agrometeorological and soil-hydrological monitoring network within the Kulunda Plain in the south of Western Siberia for 2013–2015.] // Acta Biologica Sibirica. 2016. Vol. 2. No. 2. Pp. 89–102. (In Russian.)
9. Silant'yeva M. M., Kharlamova N. F., Elesova N. V., Speranskaya N. Yu., Gal'tsova T. V., Solomonova M. Yu, Kurepina N. Yu., Plutalova T. G., Grebennikova A. Yu. Restavratsiya stepnykh ekosistem sukhostepnoy zony Kulundy s uchetom istoricheskoy rekonstruktsii rastitel'nogo pokrova [Restoration of steppe ecosystems in the

dry-steppe zone of Kulunda, taking into account the historical reconstruction of the vegetation cover] // Vestnik Altayskoy nauki. 2015, No. 1 (23). Pp. 241–245. (In Russian.)

10. Kurepina N. Yu., Tsimbaley Yu. M., Plutalova T. G., Tsilikina S. V. Otsenka dinamiki opustynivaniya territorii na osnove retrospektivnogo analiza topo- i kosmokartmaterialov (na primere ob"yektov Kulundinskoy stepi) [Assessment of the dynamics of desertification of the territory on the basis of a retrospective analysis of topo- and space-map materials (on the example of objects of the Kulunda steppe)] // Izvestiya Altayskogo otdeleniya Russkogo geograficheskogo obshchestva. 2016. No. 4 (43). Pp. 30–43. (In Russian.)

11. Yakutin M. V., Andriyevskiy V. S., Anopchenko L. Yu. Osobennosti parallel'nykh suktsessiy mikroorganizmov i patsirnykh kleshchey (Akari: Oribatida) na pervykh etapakh pochvoobrazovaniya na zasolennykh substratakh v lesostepnoy zone Zapadnoy Sibiri [Features of parallel successions of microorganisms and patient mites (Akari: Oribatida) at the first stages of soil formation on saline substrates in the forest-steppe zone of Western Siberia] // Evraziatskiy entomologicheskiy zhurnal. 2017. T. 16. № 5. Pp. 470–475. (In Russian.)

12. Sen'kova L. A., Kiseleva A.O., Tskhovrebov V. S. Ekologo-geologicheskaya pasportizatsiya prirodnykh sistem Novosibirskogo Priob'ya [Ecological and geological certification of natural systems of the Novosibirsk Ob region] // Zhizn' Zemli. 2019. T. 41. No. 4. Pp. 398–410. (In Russian.)

13. Grishina L. G., Andriyevskiy V. S. Pantsirnyye kleshchi stepey Zapadnoy Sibiri i Kazakhstana [Armored mites of the steppes of Western Siberia and Kazakhstan] // Chlenistonogiye Sibiri i Dal'nego Vostoka. Novosibirsk: Nauka. 1985. Pp. 28–39. (In Russian.)

14. Lyubechanskiy I. I., Zalish L. V., Marchenko I. I., Bespalov A.N. Kolonizatsiya pochvennymi mikroartropodami obraztsov s raznymi edaficheskimi svoystvami na kamennougol'nykh vyrabotkakh v Kuzbasse (Zapadnaya Sibir') [Colonization by soil microarthropods of samples with different edaphic properties on coal mines in Kuzbass (Western Siberia)] // Evraziatskiy Entomologicheskiy zhurnal. 2019. T. 18. No. 2. Pp. 84–90. (In Russian.)

15. Vladimirova N. V., Marchenko I. I., Belanov I. P., Novgorodova T. A. Soobshchestva pochvennykh mikroartropod (Acari, Collembola) zolootvalov T·ETs v usloviyakh raznoy stepeni konservatsii [Communities of soil microarthropods (Acari, Collembola) ash dumps of thermal power plants under conditions of varying degrees of conservation] // Sibirskiy ekologicheskiy zhurnal. 2021. T. 28. No. 1. Pp. 101–114. (In Russian.)

16. Andriyevskiy V. S., Barsukov P. A. Izmeneniye naseleniya pantsirnykh kleshchey (oribatid) v pochvakh Tazovskogo poluostrova v usloviyakh atmosfernogo zagryazneniya [Changes in the population of shell mites (oribatids) in the soils of the Taz Peninsula under conditions of atmospheric pollution] // Vestnik Nizhnevartovskogo gosudarstvennogo universiteta. 2017. No. 4. Pp. 63–70. (In Russian.)

17. Skipin L. N., Udartseva O. V., Petuhova V. S., Zhilyakov E. V. Possibilities of saline soil use for the development of Ural and Siberia environment // IOP Conference Series: Earth and Environmental Science. 2018. Vol. 177 (1). Article number 012038. DOI: 10.1088/1755-1315/177/1/012038.

18. Ustinov M. T., Gavrilov D. A., Elizarov N. V. Istoricheskiye aspekty razvitiya melioratsii zemel' v Zapadnoy Sibiri [Historical aspects of the development of land reclamation in Western Siberia] // Pochvy y и okrúżauśáa sreda. 2021. Vol. 4. No. 2. Pp. 68–80. (In Russian.)

19. Sayb E. A., Shaporina N. A. Sovremennoye sostoyaniye i perspektivy oroshayemogo zemledeliya yuga Zapadnoy Sibiri [Current state and prospects of irrigated agriculture in the south of Western Siberia] // Mezhdunarodnyy zhurnal prikladnykh i fundamental'nykh issledovaniy. 2019. No. 4. Pp. 177–183. (In Russian.)

20. Yakutin M. V., Andriyevskiy V. S., Anopchenko L. Yu. Osobennosti parallel'nykh suktsessiy mikroorganizmov i patsirnykh kleshchey (Akari: Oribatida) na pervykh etapakh pochvoobrazovaniya na zasolennykh substratakh v lesostepnoy zone Zapadnoy Sibiri [Features of parallel successions of microorganisms and patient mites (Akari: Oribatida) at the first stages of soil formation on saline substrates in the forest-steppe zone of Western Siberia] // Evraziatskiy entomologicheskiy zhurnal. 2017. T. 16. No. 5. Pp. 470–475. (In Russian.)

21. Mordkovich V. G., Lyubechanskiy I. I. Pochvennyye bespozvonochnyye Russkogo lesostep'ya (obzor publikatsiy XX–XXI vv. i reviziya rezul'tatov) [Soil invertebrates of the Russian forest-steppe (review of publications of the XX–XXI centuries and revision of the results)] // Pochvy y и okrúżauśáa sreda. 2021. T. 3. No. 4. Pp. 6–40. (In Russian.)

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