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Microzonal Distribution of Soils and Plants along the Catenas of Mound Structures

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Abstract—The results obtained during a complex study of soils and plants on mounds located in four subzones of forest steppe and steppe are presented. Having studied the vertical microzoning of the mounds, general and specific features of the distribution of soil properties (based on 40 indicators) have been shown in their geographical, catenary, and expository aspects. Functional changes have been found in the interdependence between soil and plant, which developed as a result of the thousands years of evolution of the ecosystems.

Keywords: mounds, steppe vegetation, soil catena, habitats, ecological niche, biodiversity, geoarchaeology

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INTRODUCTION

According to the Convention Concerning the Protection of the World Cultural and Natural Heritage (UNESCO), it is recommended to preserve cultural monuments along with their natural surroundings. Alongside monuments and artifacts, cultural heritage includes landscapes and their components (Davidson and Wilson, 2006). The soil–vegetation cover in numerous artificial or transformed cultural and historical stationary objects (archeological and historical monuments, ancient human settlements, fortresses, towers, ramparts, old allotment sites and their boundaries (landmarks), defense banks, burial mounds, and mounds) has been already actively studied (Lisetskii, 1999; Barczi 2003; Moysiyenko and Sudnik-Wójcikowska, 2006; Demkin et al., 2008; Sudnik-Wójcikowska and Moysiyenko 2006, 2012; Mitusov et al., 2009; Lisetskii, 2012).

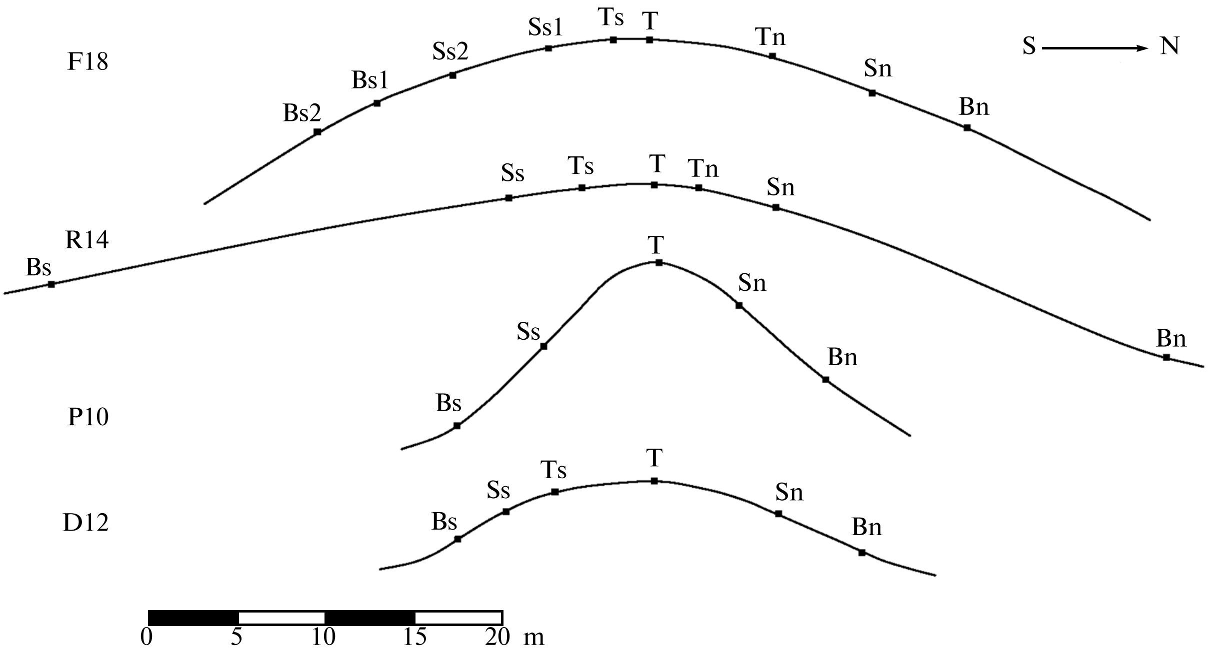
The landscape of virgin steppes cannot be considered without mounds. They have been dominant landscape units of these areas for thousands of years. In the first half of the 19th century, the territory of Southern Ukraine was represented by a specific landscape: “it is a vast steppe area, which is cut by numerous rivers and gullies. There are thousands of ancient graves and mounds and few trees” (Skal’kovskii, 2007, p. 12).

The earthworks built by ancient humans, “steppe pyramids,” are not only valuable archeological objects. They are also unique natural landmarks which may be considered irreproducible models of natural processes. These models are of certain interest, because their polar slopes are located at a small linear distance from each other, their dated soil cover developed at a homogenous substrate. It is true (Demkin, 1997) that all complex geoarcheological investigations of such monuments, including mounds, were focused on pedochronological series and provided little data on day surface series. The earlier study performed on the vegetation and soils of the Hungarian mounds (Barczi, 2003) showed that the morphological homogeneity of soils on the mounds does not reflect the high diversity of their plant species.

Research problems such as revealing the relationships between soil and environment based on the regional and local features of landscape zones and solving a number of problems associated with the mechanisms of biodiversity enabled by soils are considered (Dergacheva, 2009) among the most important and urgent issues of soil ecology. The aim of this work is to find edaphic differences along the catenas of mound structures, which are determined by the properties of soils, and to estimate their relationships with the structure of plant cover.

MATERIALS AND METHODS

The key mounds (figure) singled out for this study are located along the transect in Cherkasy, Mykolaiv, and Kherson oblasts of Ukraine: within the area of meadow steppes and broad-leaved forests on typical chernozems (F18 mound), forb and forb-rich grass steppes on common chernozems (R14), grass steppes on southern chernozems (P10), and desert steppes on chestnut soils (D12). The mounds stretch from 49°02′ to 46°23′ N. Their height varies from 6 to 7.5 m. Currently the mounds are surrounded by agrolandscapes and are island ecosystems that include some floral elements of areas near the water divide and have a specific



Lengthwise profiles through the studied mounds and areas where the soil samples were taken: T is top, Tn and Ts are rims of the northern and southern slope, Sn and Ss are average northern and southern parts of the slopes, and Bn and Bs are bottom northern and southern parts of the slopes.

soil cover dated to the zonal soil climax with the inherited properties of transplanted and mixed soils.

Morphometric parameters of the mounds were determined with the help of a theodolite survey. Landscape profiles of the catenas of differently exposed slopes oriented in the direction from north to south. In order to study differences of the plant cover in each ecotope (top, northern and southern slopes, northern and southern feet), lists of plant species were made in spring, summer, and autumn. In total, 312 plant species were recorded on four mounds. The methods of geobotanical study are described in detail in (Sudnik-Wójcikowska and Moysiyenko, 2012).

To analyze the edaphic conditions in each of 5–7 ecotopes, which are most common in the mounds, soil samples were taken along the genetic horizons of the newly formed soils (Table 1).

Agrochemical parameters (Table 2) were the content of humus (by Tyurin) and labile organic matter (by Egorov), soluble salts, CO_2 carbonates, easily hydrolyzed nitrogen (by Cornfield), mobile forms of P and K, and pH and the cluster analysis of humus (by Ponomareva and Plotnikova).

Geochemical characteristics (Table 3) are based on the elemental analysis of soils (20 elements) using the Spektroskan MAKS-GV X-ray fluorescence analyzer. Based on these data, $SiO_2/10R_2O_3$ indicator, eluviation coefficients (C_E), and Shaw's modified coefficient of accumulation of the microelements (R) were calculated. C_E was calculated as the ratio between the content of silica to the total content of calcium, potassium, manganese, and magnesium oxides. R was determined based on the elements with stably increased geochemical background (Cu, Zn, Pb, and V).

In order to solve a series of problems of this study, the methods of multivariate statistics (factor, cluster, and discriminate analyses) were applied in STATISTICA v. 6.0.

RESULTS AND DISCUSSION

If we consider mounds as a particular type of landscapes, they are geocomplexes which have a shape of blunt circular cone with the facies of a dome-shaped top, often anthropogenically disturbed, with xeromorphic plants, as well as differently exposed slopes and a gully with mesophytic plants. As a result of applicative evolution, specific soils developed. They fall into genetic chains (catenas) based on their topographic gradient (Lisetskii, 1999). Since there is a regular combination of some facies (geotopes) within topocatenas, their dynamic conjugation, and genetic unity, a mound can be regarded as such morphological unit of landscapes as a simple urochishche. Because mounds are different tin height and diameter, the area of its lateral side varies from 1200 to 102450 m^2.

The term catena has been recently used in a wider sense, because the soil–hydrological and landscape–geochemical aspects of its meaning were supplemented with soil-evolutional data. It was favored by the results obtained during the study of topocatenas at the dated objects, including those created by humans.

In the steppe zone of Eastern Europe, burial earthworks (mounds) were built starting from the Eneolithic period until the 14th century AD. For this reason, the age of soils which developed on them may

Table 1. Description of soil objects at the mound catenas

Microzone	Distance from the top, m	Slope angle, deg	Depth, cm	Color of soil (by Munsell)		HCl effervescence, cm
				dry	moist	
F18 mound (Cherkasy oblast, Chigirinskii district)						
Tn	6.94	7°38′	0–14 14–40	2.5Y4/2 2.5Y5/2	10YR3/2 10YR3/3	>
Sn	12.56	14°10′	5–27 27–43	2.5Y3/2 5Y2.5/2	10YR2/1 10YR2/2	>
Bn	17.89	16°29′	5–32 32–60	10YR3/2 2.5Y3/2	10YR2/2 10YR2/2	48
Ts	2.05	0°45′	3–20 20–31	5Y3/2 10YR4/2	10YR2/1 10YR2/2	>
Ss	5.67	4°54′	3–20 20–32	5Y3/2 2.5Y4/2	10YR2/2 10YR3/2	5
Ss	11.08	10°33′	5–23 23–43	10YR4/2 5Y2.5/2	10YR3/1 10YR2/1	10
Bs	15.37	13°51′	[31–54] [54–78]	5Y4/2 10YR4/2	10YR3/1 10YR2/2	>
Field	200	0	5–15 15–33 33–61	10YR4/1 2.5Y4/2 10YR4/3	10YR3/1 10YR4/1 10YR3/3	45
R14 mound (Mykolaiv oblast, Domanevskii district)						
T	0	0	2.5–25 25–36 >36	10YR3/3 10YR3/2.5 10YR4/2	10YR3.5/2 10YR2.5/2 10YR2.5/2	23
Sn	9.31	13°43′	0–30 30–59 59–105	10YR3/1.5 10YR3/2 10YR4/2	10YR3/2 10YR3/1.5 10YR3/1	71
Bn	28.84	19°27′	10–39 39–46.5 46.5–85	10YR3/1 10YR4/2.5 10YR4/2.5	10YR4/1 10YR3/2 10YR3/2	45
Ss	12.55	5°21′	0–23 23–45 45–78	10YR3/2 10YR4/2 10YR4/2	10YR3/2 10YR3/2 10YR3/2	19.5
Bs	30.24	8°59′	0–18 18–34 34–50	10YR3/1 10YR3/1.5 10YR3/2	10YR2/1 10YR3/1 10YR3/1	46
Field	500	0	0–38 38–65	Undefined Undefined	Undefined Undefined	45

Table1. (Contd.)

Microzone	Distance from the top, m	Slope angle, deg.	Depth, cm	Color of soil (by Munsell)		HCl effervescence, cm
				dry	moist	
P-10 mound (Kherson oblast, Berislavskii district)						
T	0	0	0–19 19–30 30–49 >49	2.5Y4/2 0YR5/3 10YR5/3 10YR6/1	10YR3/3 10YR3/2 10YR3/3 10YR3/3	7
Sn	7.64	18°00′	0–32 32–48	10YR4/2 2.5Y4/2	10YR2/2 10YR3/3	32
Bn	14.47	22°38′	0–41 41–67	10YR4/2 2.5Y4/2	10YR2/2 10YR3/3	57
Ss	5.05	14°34′	0–15 15–31	10YR5/3 10YR5/3	10YR3/3 10YR4/2	>
Bs	11.29	11°11′	0–24 24–34	2.5Y5/2 10YR5/3	10YR2/2 10YR3/2	39
Field	92	0	0–34 34–62	2.5Y4/2 10YR5/3	10YR3/3 10YR3/2	65
D12 mound (Kherson oblast, Golopristanskii district)						
T	0	0	0–6 6–22 22–37 37–53 >53	2.5Y4/2 10YR4/2 10YR4/2 2.5Y4/2 2.5Y4/2	10YR2/2 10YR2/2 10YR3/2 10YR3/2 10YR3/2	42
Sn	6.92	16°21′	0–19 19–37 37–51	2.5Y4/2 2.5Y4/2 2.5Y5/2	10YR2/2 10YR3/2 10YR3/3	19
Bn	11.69	19°44′	0–23 23–37 37–47	2.5Y3/2 10YR4/2 10YR4/2	10YR2/1 10YR3/2 10YR3/2	18
Ss	8.37	11°54′	0–26 26–36 >36	2.5Y4/2 2.5Y5/2 2.5Y5/2	10YR3/2 10YR3/2 10YR3/3	18
Bs	11.6	19°05′	0–10 10–32 32–52	10YR4/2 2.5Y4/2 2.5Y4/2	10YR2/2 10YR2/2 10YR3/3	46
Field	250	0	0–31 31–49	2.5Y4/2 10YR6/1	10YR3/2 10YR3/3	31

Here and in Table 2: T—top; Tn and Ts—the northern and southern rim of the slope, Sn and Ss—average northern and southern parts of the slopes, and Bn and Bs—the lower part of the northern and southern slopes. At a depth of effervescence with HCl greater than the lower boundary of the studied horizons used the symbol >.

significantly vary: from 600 to 4500 years. The mounds, during both Bronze and Scythian times, were built, according to archaeologists (Androsov, 1989), but according to soil scientists (Demkin, 1997; Chendev, 2008) state that the main building material was either soil taken from a circular or U-shaped gully or a mixture of upper soil horizons from the area around the mound. In any case, when building the mounds, the transplants made by humans carried floral (with roots and seeds) and microbiotic elements from the surrounding native steppe cenoses, which are not found any more. What is more, the steppes near these mounds had a significant influence on the biota until they were plowed.

The mounds often serve as graves, which were made in the later period and accompanied by adding new soil layers with different thicknesses. For example, based on the results of archaeological investigations between the mouths of the Danube and Dniester Rivers (Subbotin et al., 1995), it was revealed that 43 mounds had about 12–13 graves which belong to different cultures and historical periods (from 36th century BC to 14th century AD).

If we consider the process of pedogenesis, the period during which the mounds were built (completed) was characterized by the bioclimatic evolution of soils and a decrease in the soil-forming potential of the environment (after the thermal maximum of the

Table 2. Chemical properties of soils in the mound microzones

Mound	Position on catena	Layers*	pH (H_2O)	CO_2	Salts (dry residue)	Humus	Lab. humus	P_2O_5 (total)	K_2O (total)	N**	P_2O_5 (mob.)	K_2O (exchan.)
		cm		%						mg/kg		
F18	Tn	0–14	8.25	4.88	0.16	2.50	0.065	0.17	2.08	53.20	122	84
	Tn	14–40	8.51	5.48	0.10	1.40	0.034	0.16	2.10	31.50	115	57
	Ts	3–20	8.22	3.23	0.11	2.60	0.065	0.18	1.89	55.30	181	57
	Ts	20–31	8.36	4.88	0.10	1.80	0.043	0.17	1.78	37.10	172	95
	Sn	5–27	8.32	1.79	0.11	2.25	0.069	0.14	2.03	49.70	104	65
	Sn	27–43	8.28	2.48	0.13	1.90	0.039	0.14	2.12	36.40	76	60
	Bn	5–32	7.98	0.96	0.13	2.10	0.086	0.14	2.01	57.40	6	63
	Bn	32–60	8.25	0.86	0.13	1.70	0.034	0.12	1.94	42.00	104	81
	Ss	3–20	8.46	3.63	0.11	2.40	0.043	0.15	1.77	47.60	208	63
	Ss	20–32	8.60	2.58	0.14	1.50	0.030	0.13	1.76	30.10	154	76
	Ss	5–23	8.42	2.30	0.13	1.85	0.034	0.15	1.88	33.60	214	62
	Ss	23–43	8.45	2.44	0.09	1.40	0.026	0.15	2.02	25.20	215	62
	Bs	[31–54]	8.47	2.77	0.12	1.40	0.034	0.17	1.89	33.60	265	63
	Bs	[54–78]	8.44	3.04	0.07	1.10	0.043	0.16	1.83	23.80	328	62
R14	T	2.5–25	8.10	2.51	0.09	3.70	0.125	0.26	2.25	68.60	485	41
	T	25–36	8.35	5.15	0.09	3.50	0.082	0.22	2.06	49.00	39	101
	Sn	0–30	7.30	1.82	0.14	6.20	0.034	0.21	2.21	119.00	87	62
	Sn	30–59	7.35	1.65	0.13	4.40	0.198	0.18	2.21	77.70	69	46
	Sn	59–105	8.40	4.29	0.14	3.00	0.076	0.16	2.06	41.30	91	34
	Bn	10–39	8.50	2.54	0.12	4.90	0.129	0.20	2.22	74.90	62	41
	Bn	39–46.5	8.50	3.70	0.14	4.10	0.095	0.17	2.17	47.60	6	84
	Bn	46.5–85	8.50	5.81	0.07	3.50	0.077	0.16	2.12	36.40	4	99
	Ss	0–23	8.40	2.64	0.09	3.50	0.086	0.17	2.19	57.40	19	105
	Ss	23–45	8.45	3.96	0.12	2.80	0.061	0.17	2.19	35.70	15	86
	Ss	45–78	8.50	3.76	0.12	3.00	0.052	0.16	2.15	31.50	18	90
	Bs	0–18	7.95	2.05	0.12	5.20	0.034	0.18	2.32	91.00	18	322
	Bs	18–34	7.75	2.31	0.12	3.80	0.142	0.18	2.31	64.40	15	158
	Bs	34–50	7.70	1.85	0.09	4.40	0.120	0.20	2.31	60.90	233	59
P10	T	0–19	8.72	4.75	0.10	2.50	0.043	0.20	1.86	54.60	33	127
	T	19–30	8.63	6.14	0.07	1.45	0.043	0.18	1.95	34.30	15	82
	Sn	0–32	8.01	1.12	0.09	2.20	0.069	0.16	2.04	62.30	118	73
	Sn	32–48	8.42	3.43	0.14	2.00	0.034	0.16	2.01	44.80	8	92
	Bn	0–41	8.16	1.72	0.14	3.10	0.186	0.16	2.05	91.70	97	93
	Bn	41–67	8.32	1.72	0.13	1.50	0.043	0.14	1.99	39.20	7	70
	Ss	0–15	8.47	3.89	0.07	1.90	0.043	0.16	2.08	44.80	15	138
	Ss	15–31	8.10	4.95	0.07	1.20	0.034	0.14	2.02	26.60	6	69
	Bs	0–24	7.99	1.45	0.07	2.40	0.072	0.14	2.15	59.50	236	287
	Bs	24–34	8.42	1.06	0.07	1.80	0.043	0.12	2.13	35.70	165	239

Table 2. (Contd.)

Mound	Position on catena	Layers*	pH (H_2O)	CO_2	Salts (dry residue)	Humus	Lab. humus	P_2O_5 (total)	K_2O (total)	N**	P_2O_5 (mob.)	K_2O (exchan.)
		cm		%						mg/kg		
D12	T	0–6	8.60	1.06	0.09	1.75	0.105	0.23	2.24	42.70	842	286
	T	6–22	8.70	0.79	0.09	1.20	0.061	0.28	2.19	27.30	1087	313
	T	22–37	8.98	1.52	0.09	1.10	0.052	0.27	2.17	28.70	1035	319
	Sn	0–19	8.66	0.26	0.04	2.00	0.129	0.21	2.09	56.70	34	259
	Sn	19–37	8.85	2.29	0.11	1.90	0.069	0.21	2.11	36.40	30	268
	Bn	0–23	8.80	1.45	0.09	2.40	0.138	0.19	2.11	72.80	19	262
	Bn	23–37	8.85	3.56	0.09	1.90	0.069	0.18	1.91	37.10	26	197
	Bn	37–47	9.50	4.69	0.19	1.50	0.065	0.19	1.87	32.90	18	143
	Ss	0–26	8.32	1.22	0.10	1.15	0.069	0.20	2.01	31.50	43	353
	Ss	26–36	8.81	0.86	0.12	1.00	0.043	0.25	2.01	27.30	53	323
	Bs	0–10	8.39	0.53	0.10	1.40	0.099	0.15	1.92	42.00	452	260
	Bs	10–32	9.09	0.40	0.14	1.00	0.052	0.16	1.93	22.40	31	330

* Layers in the square brackets were buried humic material of the mound terrace. ** Easily hydrolyzed nitrogen. Mobile forms of phosphor and potassium were determined by Chirikov (numbers are underlined) in noncarbonate soils and by Machigin in carbonate soils.

Holocene period took place 5000 years ago) (Aleksandrovskii and Aleksandrovskaya, 2005). However, the Holocene soil formation was not only direct but periodic as well. This was determined, in particular, by the fact that the peaks of solar activity were marked by the lowest rates of soil formation, which is probably due to the intensification of denudation processes: in the Late Bronze (date of extrema 2950 years ago), as well as in the Roman (2050 years ago) and Middle (950 years ago) ages (Ivanov and Lisetskiy, 1996). Changes in the productivity of zonal vegetation also varied. Thus, the annual productivity of steppe ecosystems was 22–29% higher 4000–2700 and 1700–600 years ago when compared to the entire Holocene (Lisetskii, 1997). However, it should be pointed out that the last 3500 years were more favorable for the development of steppe ecosystems than in the Holocene taken as a whole.

In order to estimate the maturity of mound ecosystems, it is important to date these earth works. However, only archaeological excavation allows us to do this. We managed to date the northernmost mound (F18). Due to the old damages on its top, undisturbed soils were found only in the additional parts, where the thickness of humus horizons turned out to be equal (430 mm). The application of the earlier developed pedochronological method of dating, which is based on the model of humus formation in the foret-steppe zone in time (Goleusov and Lisetskii, 2008), made it possible to find the age of soils (2469 years). This corresponds to the beginning of soil formation from the middle of the 5th century BC.

The mound in the steppe zone (P10) is damaged in the center of its top due to the construction of a triangulation point and because of an old burglarious excavation. Nevertheless, it was still possible to find automorphic soils in the near-rim part of the northern slope. The morphology of this soil made it possible to reveal that the mound was built during the Early Bronze Age (4100 years ago). The dating was performed by pedochronological method using the model developed for southern chernozems (Goleusov and Lisetskii, 2009).

Most of the ecosystem is indicated by the component that has the longest characteristic time (Lisetskii, 1998). The recovery succession of steppe phytocenoses, which takes place after the anthropogenic affect, reaches maturity (quasiclimax) in about 100–150 years. The recovery of humus profile of soils in the renaturation regime takes a much longer period of time: 2500–3000 years.

It is known (Buol et al., 1980) that the effect produced by the mother rock on the development of soil is maximal at the early stage of pedogenesis and decreases with time as the processes of weathering and soil formation get more intense. The development of newly formed soils on the soil-ground terrace of the mounds has a superimposed (applicative) manner, which is marked by the rapid pedogenesis. The applicative soil profile inherits all transformations which occurred in the mother rock due to the influence of a soil precursor (Goleusov, 2012). During the recovery of young ecosystems, the role played by the biotic factor becomes more important and their functional stability is related, first and foremost, to the regulation of production and destruction processes.

The mounds are characterized by the vertical microzoning of their slopes with the highest contrast of environmental conditions on the polar slopes. According to the topographic gradient, all microzones form a common paragenetic complex. The systematically important relations are mainly horizonal substance-energy fluxes. The landscape microzones are characterized by specific ecological conditions which allow one to single out so-called microhabitats.

The distribution of solar radiation at the local level is determined by geographical location (relief), which

Table 3. Results of the elemental analysis of soils on the mounds and calculated values of geochemical indicators

Mound	Position in catena	Layers, cm	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	TiO_2	MnO	Zn	Ni	Cu	Pb	V	$SiO_2/10R_2O_3$	C_E	R
			%							ppm							
F18	Tn	0–14	75.7	2.7	7.7	2.2	1.1	0.7	0.4	30.8	10.4	12.7	10.3	65.4	0.73	12	0.93
	Tn	14–40	70.8	4.7	7.9	2.4	1.4	0.7	0.5	34.4	20.3	20.4	6.2	80.6	0.65	8	1.00
	Ts	3–20	75.1	1.1	7.6	2.5	0.7	0.7	0.5	22.5	14.0	15.7	6.8	79.7	0.71	18	0.86
	Ts	20–31	71.1	2.5	6.8	2.2	1.0	0.6	0.5	22.8	11.1	13.1	11.5	73.1	0.75	13	0.92
	Sn	5–27	67.1	4.2	6.7	2.1	1.2	0.6	0.4	30.7	11.2	13.7	12.3	59.9	0.73	9	0.97
	Sn	27–43	75.9	1.6	7.7	2.4	0.7	0.6	0.5	21.5	12.5	13.9	7.1	72.8	0.72	16	0.82
	Bn	5–32	72.5	1.1	7.2	2.6	0.6	0.7	0.6	32.0	15.1	16.7	13.6	70.5	0.70	17	1.10
	Bn	32–60	72.8	1.0	7.4	2.5	0.6	0.7	0.5	22.9	13.9	15.6	15.6	84.0	0.70	18	1.07
	Ss	3–20	69.2	3.0	6.8	2.2	1.0	0.5	0.4	28.9	14.0	16.2	7.2	59.2	0.74	11	0.87
	Ss	20–32	69.0	2.0	6.3	2.2	0.8	0.6	0.4	26.2	8.9	10.9	7.9	62.1	0.77	14	0.80
	Ss	5–23	71.2	1.6	7.0	2.4	0.7	0.6	0.5	18.5	11.8	13.9	12.2	68.2	0.72	15	0.88
	Ss	23–43	71.6	2.2	7.0	2.3	0.9	0.6	0.4	24.8	10.6	12.5	8.1	59.2	0.74	13	0.81
	Bs	[31–54]	71.0	1.9	6.7	2.3	0.7	0.6	0.5	30.7	9.6	11.3	11.1	63.2	0.76	14	0.91
	Bs	[54–78]	71.1	3.1	7.4	2.3	1.0	0.6	0.5	25.1	10.9	13.0	4.6	58.2	0.70	11	0.71
R14	T	2.5–25	66.9	1.7	12.1	4.9	1.0	0.8	1.0	405.7	42.5	39.2	24.1	97.9	0.37	11	3.22
	T	25–36	61.0	3.6	10.6	4.7	1.3	0.8	1.0	68.2	43.5	40.2	22.7	110.5	0.37	8	2.10
	T	[36–50]	63.4	4.1	11.7	4.6	1.4	0.8	1.0	69.6	38.5	35.9	19.6	104.7	0.37	7	1.96
	Sn	0–30	66.2	1.6	11.0	4.7	1.0	0.8	1.0	69.2	38.1	35.4	21.8	102.2	0.40	11	1.99
	Sn	30–59	65.0	1.6	12.2	5.3	1.1	0.8	1.2	69.3	46.7	42.9	20.3	114.4	0.35	11	2.11
	Sn	59–105	61.5	3.6	11.0	4.9	1.3	0.9	1.1	69.0	46.5	43.3	17.8	120.1	0.36	8	2.07
	Bn	10–39	66.7	1.9	11.6	4.8	1.1	0.8	1.1	62.8	42.7	39.4	16.6	99.8	0.38	11	1.85
	Bn	39–46.5	65.6	2.5	11.1	4.5	1.1	0.8	0.9	56.3	40.4	36.9	17.8	96.8	0.40	10	1.79
	Bn	46.5–85	63.1	4.2	11.1	4.5	1.5	0.8	0.9	58.4	39.7	36.9	18.6	98.9	0.38	7	1.83
	Ss	0–23	65.1	1.9	11.6	4.9	1.2	0.8	0.9	70.9	44.2	41.0	14.6	108.0	0.38	11	1.90
	Ss	23–45	65.1	3.4	12.2	4.6	1.4	0.8	0.9	62.0	39.9	37.4	16.4	108.9	0.37	8	1.85
	Ss	45–78	65.4	3.1	11.6	4.4	1.3	0.8	0.7	63.2	36.2	34.1	16.3	108.3	0.39	9	1.81
	Bs	0–18	65.9	1.6	11.1	4.9	1.0	0.8	1.2	65.8	40.5	37.3	18.3	97.0	0.38	11	1.88
	Bs	18–34	67.2	1.6	11.7	5.0	1.1	0.8	1.2	69.3	42.9	39.8	21.3	102.5	0.37	11	2.04
	Bs	34–50	67.9	1.7	11.9	4.8	1.0	0.8	1.1	64.7	40.1	37.3	16.2	99.3	0.38	11	1.82

Table 3. (Contd.)

Mound	Position in catena	Layers, cm	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	TiO_2	MnO	Zn	Ni	Cu	Pb	V	SiO_2/ $10R_2O_3$	C_E	R
			%							ppm							
P10	T	0–19	69.0	3.7	7.9	2.6	1.1	0.6	0.5	36.1	18.0	19.2	14.1	79.6	0.63	10	1.22
	T	19–30	68.6	4.5	8.4	2.5	1.3	0.7	0.5	29.5	16.2	17.7	8.0	83.1	0.60	8	1.00
	T	3049	68.7	5.0	8.3	2.4	1.5	0.6	0.4	28.4	17.3	18.6	8.9	72.0	0.61	8	0.99
	T	[49–65]	68.3	5.6	8.5	2.4	1.6	0.6	0.4	29.6	16.1	17.7	8.8	72.3	0.60	7	0.99
	Sn	0–32	74.3	1.1	8.2	2.7	0.7	0.7	0.5	30.0	17.4	18.0	10.5	75.6	0.65	17	1.05
	Sn	32–48	70.7	3.2	7.9	2.4	1.1	0.6	0.4	35.8	18.5	19.8	10.1	67.7	0.66	11	1.08
	Bn	0–41	73.9	1.1	7.7	2.6	0.7	0.6	0.6	41.3	16.2	17.8	10.1	68.3	0.68	17	1.10
	Bn	41–67	74.5	1.5	8.8	2.7	0.7	0.7	0.6	31.9	28.6	25.8	8.6	91.9	0.61	15	1.17
	Ss	0–15	72.4	3.1	8.7	2.5	1.1	0.7	0.4	32.1	16.4	17.7	8.3	80.7	0.62	11	1.02
	Ss	15–31	71.8	4.0	8.9	2.5	1.3	0.6	0.4	28.3	15.1	16.4	9.9	66.0	0.61	9	0.97
	Bs	0–24	76.3	1.1	8.1	2.5	0.7	0.6	0.5	32.5	10.9	12.8	13.3	66.2	0.68	17	1.01
	Bs	24–34	77.1	0.9	8.9	2.5	0.7	0.7	0.5	29.5	13.3	14.8	8.8	80.8	0.64	18	0.97
D12	T	0–6	79.2	1.0	8.1	2.2	0.7	0.6	0.4	26.0	9.0	10.4	6.8	65.1	0.74	18	0.76
	T	6–22	77.6	1.0	7.7	2.1	0.7	0.6	0.4	21.5	12.3	12.4	2.8	62.5	0.76	18	0.60
	T	22–37	75.8	2.0	7.4	2.0	0.9	0.5	0.4	16.7	10.2	11.5	6.0	54.9	0.77	14	0.65
	Sn	0–19	73.8	2.3	7.0	2.0	0.8	0.5	0.4	28.2	7.5	9.1	6.5	50.2	0.79	13	0.70
	Sn	19–37	71.8	4.5	7.4	2.1	1.3	0.6	0.4	24.4	9.4	11.4	5.5	61.7	0.73	9	0.72
	Bn	0–23	79.0	1.1	7.8	2.3	0.7	0.6	0.5	30.2	12.2	13.1	12.4	60.0	0.75	18	0.96
	Bn	23–37	71.6	2.9	6.7	2.2	0.9	0.6	0.4	19.7	10.2	11.4	8.3	62.0	0.77	12	0.76
	Bn	37–47	72.8	4.0	7.2	2.0	1.3	0.5	0.4	27.6	12.7	14.6	4.5	53.2	0.77	10	0.72
	Ss	0–26	75.3	0.9	6.8	2.1	0.6	0.5	0.4	22.9	9.0	10.5	8.5	53.3	0.81	19	0.75
	Ss	26–36	71.0	3.1	7.3	2.1	1.1	0.6	0.4	18.0	9.5	10.2	4.4	63.2	0.73	11	0.62
	Bs	0–10	77.7	0.7	6.5	1.9	0.5	0.5	0.4	20.1	5.2	6.2	3.4	53.3	0.89	22	0.51
	Bs	10–32	77.6	0.9	7.5	2.0	0.7	0.5	0.4	25.3	8.6	10.4	7.7	47.4	0.78	20	0.72

forms positional series of geosystems. Pedotopocatenas are combined into paragenetic units, because the soil–plant cover in the underlying microzone is the result of both specific environmental conditions and the cascade effect of the overlying microzones. The large mounds reaching 16–20 m in height are characterized by landscape microzones with a certain spectrum of vertical differentiation of soils and plants.

Based on the total amount of solar radiation during the period of vegetation (IV–IX), the highest degree of heat provision is common for the southern slopes of the mounds (4% higher than at the plane areas), especially for their upper and central parts, while the northern slopes receive 9.5% less heat when compared to the subhorizontal surfaces. Taking into consideration the plane character of steppe water divides and that the mound tops can be 20 m in height, it is important to emphasize that the microclimate is influenced by not only insolation, but also another type of exposure (advective). The wind force on the downwind slopes decreases and the turbulent interaction is related to the wind velocity, which finally influences the air temperature (Shcherbakov, 1982). During the vegetation period, the average coefficient of soil moisture (ratio of the moisture content in root layers on the slope and on the plane areas) on the slope having a concave lengthwise profile in the upper, middle, and lower parts reaches 0.95, 1.0, and 1.36 in the northern slopes, respectively. In the southern slopes, these values are 0.41, 0.53, and 0.95 (Romanova et al., 1983). Since the northern slopes are characterized by higher snow retention and slow snow melt, the soils on the slopes of southern exposure are more prone to water erosion.

The study of soils on steep slopes (25°–29°) showed (Georgi and Sakhle, 1984) that the upper layer of soil on the slope of southern exposure contains 2.6 times less humus than that on the northern slope, but the ration between passive and active humus shifts in favor of the latter: its share is 16% higher.

The color of soil, especially in its dry state, is differentiated both along the depth of the soil profile and by the ecotopes of the mounds (Table 1). It is determined by not only differences in the humus content and granulometric composition of soils, but it also reflects the established hydrothermal conditions, which is especially evident in the soils at the bottom.

Although there are pedotopocatenas at the mounds, their processes of moisture redistribution are rather subradial and not positional–dynamic. The mounds are solitary standing and, probably, characterized by a higher degree of drying. This was proved by results we obtained on one of the mounds: the moisture content of soil in the layer of 0–60 cm was 7.6% lower, and the water reserve in the layer of 0–40 cm was 1.5 times lower when compared to the neighboring plane area.

Therefore, the differentiation of soils on the topocatenas, which appeared as the new soil layer developed after the soil-ground terraces had been created (2500–4000 years ago), is explained by the specificity of regular microclimatic (and landscape) processes within particular sloping microzones.

In the modern anthropogenic landscape, the isolation of mounds from plain steppes was often, though not always, a factor affecting the basic species composition of plant communities. On the contrary, with regard to restoration ecology, the mounds may be considered source habiats (Hanski, 2005). The data of botanical investigations performed in Central and Southern Ukraine (Sudnik-Wójcikowska and Moysiyenko, 2012) on more than 100 mounds, which played the role of microcenters of biodiversity, revealed 720 species of plants. The reason may be that the mound geocomplexes are distinguished by a wide range of abiotic conditions. Thus, adapted species are capable of efficiently using their ecological niches. What is more, when environmental fluctuations take place, the close proximity of communities may favor so-called phytocenotic replaceability (Shelyag-Sosonko et al., 1991).

The factor analysis allows one to single out five component factors, which describe 49.62, 13.60, 8.93, 6.28, and 4.26% of variations. Since the first four factors taken together describe 78.44% of variations, it is appropriate to use them for further content analysis. The first factor correlates closely with many parameters and is, first and foremost, useful for identifying different ecotopes based on their soil properties. The most important soil properties are agrochemical indicators (the content of organic matter and easily hydrolyzed N), macroelements (Fe_2O_3, Al_2O_3, TiO_2, SiO_2), and microelements (Cu, Ni, V, Cr, Pb, Co, Sr). The second factor may be considered a combination of interrelated properties: CO_2 carbonates and CaO. The third factor is most dependent on the content of soluble salts and to a lesser degree determined by total phosphor. The fourth factor is determined by the availability of mobile phosphor.

Therefore, the most significant soil and geochemical processes, which determine the specific features of ecotopes at the mounds, are those related to humus accumulation, the eluvial removal of elements, lessivage, and leaching. What is more, it is probable that the eluvial removal of elements (clearly seen in factor 1) leads to the highest differentiation of ecotopes within the catenas. The increase in C_E near the southern slopes (Table 3) occurs mainly due to the accumulation of silica, which results from the higher rates of surface washoff from the southern slopes and from the accumulation of large-sized fractions of the solid flow at the decrease in the water flow velocity near the bottoms.

Having singled out four major components, we managed to reduce the number of variables and thus created a more efficient classification of ecotopes. In order to measure differences that occurred during the cluster analysis, the squared Euclidean distance was used (in order to integrate large clusters). Taking into account that differences between the soil properties of various objects are insignificant, the cluster analysis was performed by Ward's method, which allows one to increase the size of feature space. Based on the results of clusterization, the following series of objects may be singled out: R14—(D12 + P10)—F18. In other words, the mounds located in the forest steppe and in the subzone of forb–grass steppes are most specific and those belonging to the southern group and found under similar climatic conditions (annual precipitation—370–380 mm, period with the temperature >10°C—180–190 days) are little different in the sum of soil properties of their ecotopes.

The analysis of specific features in particular ecotopes indicates that there is a trend towards the formation of consolidated groups typical for the southern slopes, to which the mound tops are similar. The northern slopes are marked by the highest diversity of properties. It should be pointed out that there are statistically significant differences between the edaphic properties of the bottom areas.

The cluster analysis performed on particular objects allowed us to prove the revealed trends. It may be obviously said that the soil properties differ significantly between the northern and southern slopes and that the mound tops and bottoms tend to be totally dissimilar.

If we apply a scheme for the differentiation of edaphic properties of mound ecotopes into five types (top, northern and southern slopes, and their bottoms), it is important to find such soil properties that most clearly differentiate these ecotopes. As is seen from the results of the cluster analysis, ecotopes are rarely singled out as separate groups. They more often form groups having similar properties; i.e., soil properties define a lower number of ecotopes (2–3). For this reason it should have been suggested that only some soil properties would discriminate the five edaphotopes. Using the discriminate analysis, we performed a forward stepwise analysis with the level of tolerance equaling 0.01 for three groups of soil properties: eight agrochemical properties and the content of eight macro- and ten microelements. The discriminating variables were singled out in the first and second groups. In the third group, none of the variables may be used for the discrimination of five edaphotopes.

In the first group, the greatest contribution to the difference between the edaphotopes is made (in the order of decreasing importance): the content of $CaCO_3$ and mobile forms of K_2O and P_2O_5, labile humus, the content of easily hydrolyzed N, actual acidity. Four discriminate functions with the shares of dispersion equaling 83.7, 10.1, 5.3, and 0.9%, respectively.

The first function is most dependent on the decrease in the content of CO_2 carbonates and labile humus, as well as the content of hydrolyzed N. The second group includes only two parameters, which satisfy the conditions of our analysis: the total content of P and CaO. Thus, two discriminate functions having dispersions of 87.6 and 12.4% were determined. The first function is negatively related to the content of Ca and P, while the second is partially determined by the content of phosphor.

To prove the results of discriminate analysis, the distribution of soil properties in mound ecotopes of the same type was analyzed. The highest differences were determined by agrochemical properties of soil. Thus, the slopes of northern exposure and their bottoms are marked by the highest content of total and labile humus, as well as easily hydrolyzed N. The tops, slopes of southern exposure, and their bottoms are characterized by a higher content of mobile K and P, as well as carbonates. In addition, the tops and southern slopes have higher amounts of Ca and Mg and total P. The content of microelements in the soils of different edaphotopes is generally determined by catenary processes of washoff accumulation. It also significantly depends on substrate heterogeneity of terraces.

Our analysis allows us to definitely establish that the top and southern slope are isolated based on the content of carbonates and decreased content of nutrient elements and the northern slope of mounds are marked by higher supply with nutrient elements, but, as the same time, characterized by more significant leaching. The bottom areas of the lopes are similar in their properties, but the northern bottom is more isolated and generally more favorable based on its edaphic properties. Near the foot of the northern slope, if compared to the top of the mounds, there was an increased accumulation in soil (to 20%) of such elements essential for plants as Fe, Mn, Zn, Cu, and Ni.

Shaw's modified coefficient of accumulation of the microelements, which was calculated by us based on the formula of geometric average, is a mean clarke of the concentrations of elements (Cu, Zn, Pb, and V) in the soil system. This mean value provides a quantitative estimation of a soil system's ability to accumulate elements when compared to lithosphere. The analysis of R values (see Table 3) showed that the soils of northern slopes and their foot areas are more enriched with elements prone to accumulation than the soils on the top of the mounds.

Generally, when comparing the soil properties of different objects, it should be pointed out that they differ most significantly in the content of microelements (their variation coefficients are the highest ones). For this reason, this group of elements may hardly be used for comparing similar edaphotopes of different objects. The highest similarity between soils of the mounds was observed in the content of macroelements. In this group of properties, the most significant variation was typical for the content of R_2O_3. Soils of the objects are similar in the reaction of their media to the supply with mobile phosphor. They have no significant differences in the content of highly soluble salts. Other agrochemical properties of soils are much different. These differences may be related to both variations in the conditions of soil formation within the corresponding natural zones and specific features of mother rocks (mixture of soil-grounds).

Upon the transzonal location of the studied mounds, topological analogues (upper, central, and lower parts of the slopes) singled out within the limits of pedotopocatenas cannot be considered analogues due to the sliding migration of landscape microzones (Mil'kov, 1974), i.e., because of the movement of similar geosystems down the slope when more humid zones are replaced by less humid ones and vice-versa. In all the mounds, the coefficient of eluviation is above average for the soils near the foot of the southern slope compared to all ecotopes, including the foot of the northern slope (see Table 3).

The richness of floral species registered in the mounds is determined by the diversity of their ecological niches, which favored the development within a small territory of some zonal vegetation commonly found in the vast upland (plain) steppe to their mass plowing. The differentiation of edaphic conditions along the catenas of the mounds is reflected in the features of their plant cover. In order to find out this relationship, the method of canonical correlation analysis may be used. It considers all groups of soil properties (agrochemical, content of macro- and microelements) and the following descriptions of florae: number and total importance of species depending on their ecological group, number, and total importance of species depending on their life forms. The revealed relationships, canonical roots, are characterized by a high consistency of variables, which describe such blocks as "soil" and "phytocenosis." An interpretation of these roots is possible based on their factor loadings. In all, the results obtained during the canonical analysis allow to make the following conclusions:

(i) There is a high correlation between "soil" and "flora"; more evident relationships are revealed in the group of life forms when compared to ecological groups.

(ii) The correlations of soil properties and floral peculiarities are clearer if the total number of species, not their overall importance, is considered.

(iii) Agrochemical properties of soils determine the type of plant community. The contents of micro- and macroelements are second and third in importance, respectively. The plant communities are obviously dependent on such factors as humus content (total and labile) and mobile nutrient elements. The most important role is also played by acid and alkaline conditions in the soil solution, as well as the amount of carbonates and alkaline-earth metals.

When comparing the results of canonical and discriminate function analysis, it can be concluded that plants are more influenced not by the catenary distribution of soil properties, but rather by a specific group of properties within a particular ecotope.

It is expected that the pedotopes and phytotopes of the mounds do not coincide in terms of location. From the ecological point of view, terms such as habitat and niche can be combined only if a fundamental (potential) and not ecological (realized) niche is meant (Grodzinskii, 2005).

With regard to the territorial differentiation of plants, concentric (circum-apical) differences between the ecotopes are most evident. However, in some cases the top of either the southern slope or the northern slope and its foot gets isolated. What is more, many exceptions are observed in the extreme geographic variants, i.e., in the florae of forest steppe and desert steppes.

In the microzones of mounds at the final stage of succession, the population structure of vegetation is less than previously determined by the phytoclimate of habitat, geochemical microenvironment of the root layer, etc. The formation of species composition of the phytocenosis is more and more influenced by intracenotic processes (competition, symbiosis, secular cycles of particular populations, etc.) (Grodzinskii, 2005). Thus, at this stage of ecosystem evolution, both phytocenoses and soils become more self-regulating systems with a well developed range of negative reverse relations in the case of an increase in dominance of stochastic relationships over deterministic ones.

CONCLUSIONS

The results of an investigation into topocatenas at ancient mounds allow us to understand the evolution of the soil cover with the fixed zero moment on the scale with absolute time. However, the nonstationarity of the biota makes it appropriate to consider the subsystem "soil—vegetation" within the paragenetically related microzones (microhabitats) forming landscape-geochemical cascade systems.

Based on an analysis of distribution of soil properties along the topocatenas (using 40 parameters), it was found that the most distinctive habitats are the mound tops and the southern slopes, which are singled out based on the content of carbonates, decreased the amount of nutrient elements, as well as the northern slopes, marked by the higher amount of nutrient elements along with more intense leaching. The bottom areas of the slopes are similar in properties to a certain degree, but the foot of the northern slopes is more isolated and, generally, more favorable in its properties.

In all, the distribution of soil features both along the mounds located in different natural and climatic conditions and along the ecotopes of each mound is less clear if compared to the distribution of the corresponding florae. Soil restoration is a slower process taking a longer time when compared to the restoration of plant communities. For this reason, soils retain all local effects produced on them, especially anthropogenic ones, for a good while.

Taking into consideration the observed level of self-regulation in the ecosystems of the mounds, attention should be paid not to the interdependence between soil and plants, but to understanding the elementary soil processes according to the most informative soil properties, which are mostly determined by the influence of the biotic factor.

The differentiation of plants on the mounds is very dependent on the soil properties of particular ecotopes. The evidence is that the rise in the content of nutrient elements within the mound terrace, from the top to the northern foot, is accompanied by the increase in the species richness of the ecotopes, in particular, due to the higher number of moisture-loving, shade-enduring, and demanding soil richness species. Nevertheless, it should be considered that the actual state of plants reflects only a certain stage of recovery succession, while the soil properties fix the influence of continuous biogeochemical fluxes, which appeared over a long period of interaction between soil and plants.

The results of the cluster analysis (according to 1-Pearson) of the florae in different habitats showed that the law of precession at the topological level of geosystem regulation is not proved: the flora of the northern slopes of the mounds in the steppe zone remain quite isolated and its similarity to the flora of the southern slope in the forest-steppe mound is not revealed.

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REFERENCES

Aleksandrovskii, A.L. and Aleksandrovskaya, E.I., *Evolyutsiya pochv i geograficheskaya sreda* (Soil Evolution and Geographical Environment), Moscow: Nauka, 2005.

Androsov, A.A., Architecture of Scythian barrows of Ukraine: traditions and innovations, in *Problemy skifo-sarmatskoi arkheologii Severnogo Prichernomor'ya* (Problems of Scythian-Sarmatian Archeology of the Northern Black Sea Region), 1989, pp. 9–11.

Barczi, A., Data for the botanical and pedological surveys of the Hungarian kurgans (Great Hungarian Plain, Hortobagy), Thaiszia, *J. Bot.*, 2003, vol. 13, pp. 113–126.

Borisov, A.V., Demkina, T.S., and Demkin, V.A., *Paleopochvy i klimat Ergenei v epokhu bronzy, IV-II tys. do n.e.* (Paleosoils and Climate of Ergeninskaya Rise in the Bronze Age, IV-II Thousand Centuries B.C.), Moscow: Nauka, 2006.

Buol, S.W., Hole, F.D., and McCracken, R.J., *Soil genesis and classification,* Iowa State University Press, 1980, 2nd ed.

Chendev, Yu.G., *Evolyutsiya lesostepnykh pochv Srednerusskoi vozvyshennosti v golotsene* (Evolution of Forest-Steppe Soils of the Central Russian Upland), Moscow: GEOS, 2008.

Davidson, D.A. and Wilson, C.A., *An assessment of potential soil indicators for the preservation of Cultural Heritage*, United Kingdom: Stirling Univ., School Biol. Environ. Sci., 2006.

Demkin, V.A., *Pochvovedenie i arkheologiya* (Soil Science and Archaeology), Pushchino: Pushch. Nauchn. Tsentr, Ross. Akad. Nauk, 1997.

Demkin, V.A., Demkina, T.S., Borisov, A.V., and Khomutova, T.E., Ancient steppe kurgans as an unique archive of nature evolution, in *Prirodnoe nasledie Rossii v 21 veke* (Natural Heritage of Russia in XXI Century), Ufa, 2008, pp. 139–143.

Dergacheva, M.I., Ecology of soils: a new science of the biosphere class, *Contemp. Probl. Ecol.,* 2009, vol. 2, no. 6, pp. 625–630.

Georgi, A.A. and Sakhle, M.Z., Development of soils on the slopes of the gulls of the left-bank forest-steppe of Ukraine, *Tr. Khark. S-kh. Inst.,* 1984, vol. 299, pp. 65–67.

Goleusov, P.V., Self-organization and environmental rehabilitation of anthropogenically destroyed geosystems in the regions of intensive farming, *Extended Abstract of Doctoral (Geogr.) Dissertation*, Belgorod, 2012.

Goleusov, P.V. and Lisetskii, F.N., Soil development in anthropogenically disturbed forest-steppe landscapes, *Eurasian Soil Sci.*, 2008, vol. 41, no. 13, pp. 1480–1486.

Goleusov, P.V. and Lisetskii, F.N., *Vosproizvodstvo pochv v antropogenno narushennykh landshaftakh lesostepei* (Regeneration of Soils in Anthropogenically Disturbed Landscapes of Forest-Steppe Zone), Moscow: GEOS, 2009.

Grodzinskii, M.D., *Piznannya landshaftu: mistse i prostir: Monografiya* (Study of Landscape: Place and Space: Monograph), 2 vols., Kiev: Kiev. Univ., 2005, vol. 1.

Hanski, I., The Shrinking World: Ecological Consequences of Habitat Loss, in *Excellence in Ecology 14*, Oldendorf/Luhe, Germany: Int. Ecol. Inst., 2005.

Ivanov, I.V. and Lisetskiy, F.N., Correlation of soil formation rhythms with periodicity of solar activity over the last 5000 years, *Dokl. Earth Sci.*, 1996, vol. 340, no. 1, pp. 189–194.

Lisetskii, F.N., Autogenic succession of steppe vegetation in postantique landscapes, *Russ. J. Ecol.*, 1998, vol. 29, no. 4, pp. 252–255.

Lisetskii, F.N., Soil catenas in archeological landscapes, *Eurasian Soil Sci.*, 1999, vol. 32, no. 10, pp. 1213–1223.

Lisetskii, F.N., Soil reproduction in steppe ecosystems of different ages, *Contemp. Probl. Ecol.,* 2012, vol. 5, no. 6, pp. 580–588.

Lisetskii, F.N., Spatial and temporal evaluation of plant production as a soil-forming factor, *Eurasian Soil Sci.,* 1997, no. 9, pp. 937–939.

Mil'kov, F.N., Slope microzonality of the landscapes, *Nauchn. Zap. Voronezh. Otd. Vses. Geogr. O-va*, 1974, pp. 3–9.

Mitusov, A.V., Mitusova, O.E., Pustovoytov, K., Lubos, C.C.-M., Dreibrodt, S., and Bork, H.-R., Palaeoclimatic indicators in soils buried under archaeological monuments in the Eurasian steppe: a review, *Holocene*, 2009, vol. 19, no. 8, pp. 1153–1160.

Moysiyenko, I. and Sudnik-Wójcikowska, B., The flora of kurgans in the steppe zone of Southern Ukraine – phytogeographical and ecological aspects, *Pol. Bot. Stud.,* 2006, vol. 22, pp. 387–398.

Romanova, E.N., Mosolova, G.I., and Beresneva, I.A., *Mikroklimatologiya i ee znachenie dlya sel'skogo khozyaistva* (Role of Microclimatology in Agriculture), Leningrad: Gidrometeoizdat, 1983.

Shcherbakov, Yu.A., *Sklonovye landshafty* (Slope Landscapes), Kalinin: Kalinin. Gos. Univ., 1982.

Shelyag-Sosonko, Yu.R., Krisachenko, V.S., and Movchan, Ya.I., *Metodologiya geobotaniki* (Handbook on Geobotany), Kiev: Naukova Dumka, 1991.

Skal'kovskii, A.A., *Pervoe tridtsateletie goroda Odessy, 1793–1823: Ocherki* (First Thirty Years of Odessa City, 1793–1823: Essays), Odessa: Optimum, 2007.

Subbotin, L.V., Ostroverkhov, A.S., and Dzigovskii, A.N., *Arkheologicheskie drevnosti Budzhaka. Kurgany vostochnogo poberezh'ya ozera Sasyk* (Archaeological Antiquities of Budzhak. Kurgans of Eastern Coast of the Sasyk Lake), Odessa, 1995, pp. 106.

Sudnik-Wójcikowska, B. and Moysiyenko, I.I., *Kurhany na "Dzikich Polach" – dziedzictwo kultury i ostoja ukraińskiego stepu*, Warszawa, 2012.

Sudnik-Wójcikowska, B. and Moysiyenko, I.I., The flora of kurgans in the West-Pontic grass steppe zone of southern Ukraine, *Chornomor. Bot. Zh.*, 2006, vol. 2, no. 2, pp. 14–44.

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