ISSN 2079-0961, Arid Ecosystems, 2024, Vol. 14, No. 3, pp. 298–306. © Pleiades Publishing, Ltd., 2024.
Russian Text © The Author(s), 2024, published in Aridnye Ekosistemy, 2024, Vol. 30, No. 3(100), pp. 50–60.

SYSTEMATIC STUDY OF ARID TERRITORIES

Conservation of Soil Cover of the Steppe in Federal Specially Protected Natural Areas

O. V. Chernova[a, *] **and A. A. Prisyazhnaya**[b, **]

[a] *Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Moscow, 119071 Russia*
[b] *Institute of Fundamental Problems of Biology, Russian Academy of Sciences, Pushchino, Moscow oblast, 142290 Russia*
**e-mail: ovcher@mail.ru*
***e-mail: alla_pris@rambler.ru*

Received April 1, 2024; revised April 4, 2024; accepted April 10, 2024

Abstract—The basis of Russia's natural reserve fund consists of federal state reserves, national parks, and wildlife sanctuaries, the representativeness of which in relation to the diversity of natural complexes, including soils, is the main mechanism for protecting natural diversity. Using the method of geoinformation analysis, the areal and typological representation of the natural diversity of steppe soils in the system of specially protected natural areas (SPNAs) of the country was assessed based on vector maps: *Pochvennaya karta Rossii* (Soil Map of Russia) on a scale of 1 : 2500000 (a combined version of the *Pochvennaya karta RSFSR* (Soil Map of the RSFSR) and the *Pochvennaya karta Kryma* (Soil Map of Crimea) and the *Karty pochvenno-ekologicheskogo raionirovaniya v Rossiiskoi Federatsii* (Map of Soil-Ecological Zoning of the Russian Federation) on a scale of 1 : 8000000. The area occupied by steppe soils in Russia is 1564000 km^2 (9.4% of the total soil area of the country), of which 7.4% are soils of steppes (including forest–steppes and true steppes) and 2.0% are soils of dry steppes and semideserts. In protected areas, steppe soils occupy 11500 km^2 and are found in 23 nature reserves, 14 national parks, and 13 wildlife sanctuaries. The current areal representativeness of protected steppe areas is very low: less than 0.5% for the group "Soils of the steppes" and about 2% for the group "Soils of dry steppes and semideserts. "Of the 55 steppe soils, units of the legend of the "Soil Map of Russia," 58% are represented in federal protected areas, while reserves, which account for a fifth of the total area of steppe protected areas, provide 81% of the typological representativeness. Currently, many natural steppe soils in Russia, including the most fertile ones, are not represented in protected areas. The most significant compact array of such soils in terms of area is located in Ciscaucasia. The largest area here is occupied by southern and ordinary mycelial–carbonate chernozems (World reference base for soil resources (2014) – Calcic Chernozems (Pachic)), their area is about 98000 km^2 (7.9% of the soil area of the Russian steppes). There is a real threat of losing the last virgin examples of highly fertile soils typical of Ciscaucasia: southern and ordinary chernozems, dark chestnut, chestnut, light chestnut soils (WRB – Calcic Chernozems (Pachic), Haplic Kastanozems, Calcic/Gypsic Kastanozems, Luvic Calcisols). Preservation of these soils in the virgin state, at least as samples for comparison with anthropogenically modified analogues, requires an inventory of all areas of their distribution and assignment of a protective status.

Keywords: steppe soils, soil diversity, representativeness of protected areas, geoinformation analysis, geoinformation mapping, nature reserves, national parks, wildlife sanctuaries

DOI: 10.1134/S2079096124700240

Most of the country's agricultural lands are concentrated in the steppe and forest–steppe regions of Russia, which results in their extremely high anthropogenic variability. According to A.A. Chibilev (1999), during the 20th century, the steppe zone of Eurasia became the most damaged landscape on the planet. In the European part of Russia, entire types of steppe ecosystems, for example, meadow and true steppes, have been destroyed over more than 90% of their original area, and in some steppe regions of Siberia, the level of plowing reaches 70% (Tishkov et al., 2021a). Plain zonal steppe ecosystems, including meadow, true, dry, desert, and saz steppes, have now been practically destroyed; to a greater extent, undisturbed and slightly disturbed ecosystems of intrazonal landscapes have been preserved to a greater extent: in floodplains, in gullies, on bedrock outcrops, and on salt licks and salt marshes. The problem of progressive degradation of steppe regions (in a broad sense, from forest–steppes to semideserts) is currently very acute and is actively being discussed. Thus, various aspects of the strategy for preserving the diversity of steppe ecosystems and rational environmental management are discussed in the works of A.A. Chibilev et al. (Chibilev, 2022; Gulyanov and Chibilev, 2019; Chibilev et al., 2021, 2019). A number of works by A.A. Tishkov et al. (Tishkov and Nekrich, 2022; Tishkov et al., 2021b, 2020) are devoted to consideration of the dynamics of the biosphere parameters of steppe ecosystems at the regional and global levels, as well as the development of strategies for the conservation and restoration of biological diversity in conditions of high anthropogenic transformation.

Anthropogenic transformation of steppe territories has led to transformation of the soil cover. Chernozems, which in Russia form the basis of the arable fund, have been changed to the greatest extent by agricultural use: by the beginning of the 21st century, their share in the total arable area was 52.6% (Romanenko et al., 1996). Currently, chernozem regions continue to be the breadbasket of the country; pressure on them is growing due to land abandonment and a decrease in the scale of agricultural production in regions with less favorable climatic and soil conditions. A high degree of plowing, pasture press, intensive development, and exploitation of oil and gas fields, as well as increased urbanization, has led to a decrease in the area of natural ecosystems, increased erosion and deflation, and decreased fertility and soil degradation. Modern plowing of chernozems exceeds 70%; in some regions this percentage reaches 80%, despite the fact that, according to various estimates, it should not exceed 60%, and the optimal parameters are 40–45% (*Natsional'nyi atlas pochv*, 2011; Orlova, 2006).

The decline in biological diversity is constantly the focus of attention of environmental organizations and departments, which cannot be said about soil diversity. Moreover, the typological diversity of soils is largely related to the diversity of ecosystems. Soil scientists drew attention to the ecological, environment-forming functions of soils (gas, water regulation, sanitation) at the end of the last century (Dobrovolsky and Nikitin, 1990; Daily, 1997), but only recently, the threat of global climate change has drawn increasing attention to the carbon-sequestration potential of the soil cover and its role as a central hub in the biological cycle of elements. In addition, the spatial heterogeneity of the pedosphere at all levels, from microaggregates to the complexity of the soil cover, ensures the coexistence of a huge diversity of plant, animal, and microorganism species in terrestrial ecosystems (Ibàñez et al, 1995; Amundson 2000; Dobrovolsky et al., 2011).

The main mechanism for maintaining biological diversity is considered to be its conservation within specially protected natural areas (SPNA); however, when planning the development of the state system of protected areas (PA), the need to protect the diversity of natural soils has thus far been ignored despite the fact that there are a number of studies devoted to the analysis of the representativeness of the PA system regarding soil diversity (Chernova, 2012; Prisyazhnaya et al., 2016). Increasing the representativeness of PA of steppe land in terms of soil diversity is especially important in the context of increasing anthropogenic impact and climate change, since it is in herbaceous ecosystems that the share of soil in the sequestration and deposition of biophilic elements, in particular carbon, is maximum. A comparative analysis of available estimates of the productivity and reserves of organic matter in the underground and aboveground parts of herbaceous ecosystems showed that their aboveground biomass is significantly inferior to the underground one, sometimes many times, both in terms of the mass of organic matter and in the annual increase in phytomass (Abaturov, 2023). The share of soils in the total carbon reserves of steppe ecosystems exceeds 90%, in contrast to 25–45% (including litter) characteristic of forest soils (Chernova et al., 2020).

The purpose of this work is to assess the representation of the natural diversity of steppe soils in Russia in the system of protected areas at the federal level.

MATERIALS AND METHODS

Geoinformation analysis of the representativeness of federal protected areas of the Russian Federation (state reserves, national parks, and wildlife sanctuaries) was carried out in the ArcView GIS system. The boundaries of the protected areas are digitized in accordance with the established documents of the protected areas and information from the website "Specially Protected Natural Areas of Russia" (2024).

This study was carried out on the basis of a vector version of the *Pochvennaya karta RSFSR* (Soil Map of the RSFSR) (1988) on a scale of 1 : 2500000, which was supplemented by the *Pochvennaya karta Kryma* (Soil Map of Crimea) (Urusevskaya et al., 2019b) of the same scale, made in accordance with the ideology and legend of the *Pochvennaya karta RSFSR* (Soil Map of the RSFSR). The modern version of the *Pochvennaya karta Rossii* (Soil Map of Russia) (hereinafter referred to as SMR) is presented on the website of the Soil Data Center of Moscow State University (2024).

Based on the combined SMR, the composition of the soil cover of federal protected areas and the representativeness of soil diversity were analyzed in accordance with two sections of the map legend ("Soils of the steppes" and "Soils of dry steppes and semideserts"), including 55 cartographic units. Soil complexes are taken into account based on the predominant soil (the first soil in the name of the complex), since the areal relationships of their composition are not shown on the map. When discussing the representation of soil diversity on the territory of Russia and within protected areas, the names of soil units of the SMR legend were used, and the names of the corresponding soils according to the World reference base for soil resources (2014), hereinafter referred to as WRB, were also given.

When considering the representativeness of the federal system of protected areas in relation to soil cover structures typical for various regions, we were guided by the *Karta pochvenno-ekologicheskogo raionirovaniya Rossiiskoi Federatsii* (Map of Soil-Ecological Zoning of the Russian Federation) (hereinafter referred to as SEZ) (Urusevskaya et al., 2019a). Representativeness was assessed at the level of SEZ reference units, which in flat conditions is a soil zone (subzone), and in mountains, a mountain soil province. According to the SEZ map, four soil zones of steppe plain territories are identified on the territory of Russia, including 23 plain soil provinces and six mountain soil provinces, in the lowlands of which steppe soils with corresponding ecosystems predominate. Within the zones, plains, and mountain soil provinces, the presence of federal-level protected areas, nature reserves, national parks, and wildlife sanctuaries, as well as their representativeness, was assessed based on a comparison of the soil cover of the protected areas and the territorial unit of the SEZ as a whole. Thus, the composition of the soil cover of protected areas located within the steppe zones of the SEZ map was analyzed: zones of podzolized, leached, and typical chernozems and gray forest soils of the forest–steppe, zones of ordinary and southern chernozems of the steppe, zones of dark chestnut and chestnut soils of the dry steppe, zones of light chestnut and brown soils of the semidesert, and the above-mentioned mountain soil provinces of the Subboreal belt.

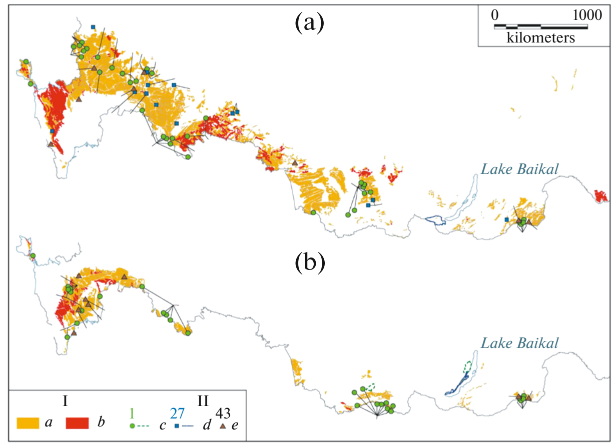

Fig. 1. Soils of the Russian steppes. Distribution and representation in federal SPNA. (a) Soils and soil complexes of the steppe group; (b) soils and soil complexes of the group of dry steppes and semideserts. I—Soil map units: *a*—found in protected areas, *b*—not found in protected areas. II—Federal protected areas: *c*—nature reserves, *d*—national parks, *e*—wildlife sanctuaries (the number corresponds to the name of the protected area in the table).

RESULTS AND DISCUSSION

Federal protected areas of the steppe regions. According to a cartographic assessment based on the SEZ map, in the steppe regions of the country there are currently 61 federal-level protected areas (26 state reserves, 16 national parks, and 19 wildlife sanctuaries), including 16 mountain protected areas, involving steppe landscapes of low mountains and intermountain depressions (eight reserves and seven national parks, and one wildlife sanctuary; Table 1).

The total area of soil cover in steppe natural protected areas (without water areas and nonsoil formations) is 57 000 km^2: 21 000 km^2 falls on nature reserves; 24000 km^2, to national parks; and 12000 km^2, to wildlife sanctuaries. However, many protected areas are confined to intrazonal positions: floodplain and ravine landscapes, wetlands, and outcrops of atypical soil-forming rocks. Of the 26 state reserves in the steppe regions of Russia, only five have the majority of their area occupied by steppe soils with corresponding ecosystems. In 20 (out of 61) federal protected areas of steppe regions, steppe soils are not represented at all or occupy an area of less than 5% of the territory (Table 1).

Areal and typological representation of soils in federal steppe protected areas. The representativeness of the network of steppe protected areas at the federal level in relation to soil cover was assessed on the basis of the SMR information according to two parameters: areal representation, which is the relative area of steppe soils within the SPNA, and typological, which is the number of soil varieties (at the level of units of the SMR legend) found in the protected areas.

In Russia, steppe soils occupy 1 564 000 km^2, which is 9.4% of its soil area, of which 1 238 000 km^2 (7.4%) belong to the group "Soils of the steppes" and 326 000 km^2 (2.0%) go with the group "Soils of dry steppes and semideserts." The areas of soils and soil complexes of steppe regions are presented on 50 protected natural areas of federal status: in 23 reserves, 14 national parks, and 13 wildlife sanctuaries. The distribution of steppe soils in Russia and the location of federal protected areas in which these soils occur is shown in Fig. 1. Steppe soils can occupy a very small area, less than 100 hectares, or spread over almost the entire protected area. The total area of steppe soils in protected areas is 11 500 km^2 (21% each fall on nature reserves and national parks, 58% on wildlife sanctuaries).

Areal representation of the steppe soils and soil complexes in federal protected areas is assessed separately for the soil groups of steppes and dry steppes and semideserts (Fig. 2). The representativeness turned out to be very low, less than 0.5% of the total area of steppe soils in the country and about 2% of the area of the group of soils of dry steppes and semideserts. This is noticeably lower than the indicators characterizing other large groups of soils in Russia: according to our calculations, 7.7% for soils in mountainous areas, 6.1% for soils in the Arctic and tundra, and 4.3% for soils in broad-leaved forests. The situation is especially tense with state reserves: the areal representation of soils and soil complexes of steppes is only 0.07%, and that of dry steppes and semideserts is less than 0.5%.

Table 1. Area of steppe soils in protected areas, % of the area of protected areas

SPNA	More than 80		30–80		5–30		Less than 5	
	no.	name	no.	name	no.	name	no.	name
State nature reserves	1	Belogorye	6	Rostovskii	9	Voronezh	19	Astrakhan
	2	Bogdinsko-Baskunchaksky	7	Khoperskii	10	Voroninskii	20	**Baikal-Lenskii**
	3	Orenburgskii	8	Black lands	11	**Dagestan**	21	Galichya Mountain
	4	Central Chernozem			12	Daurskii	22	Zhigulevskii
	5	**Shaitan Tau***			13	**Ilmenskii**	23	Swan Islands
					14	Kazantipskii	24	Prisurskii
					15	Opukskii	25	**Sayano-Shushenskii**
					16	Volga forest–steppe	26	**Ubsunur Basin**
					17	**Tigirekskii**		
					18	**Khakassian**		
National parks	27	Khvalynskii	29	Chavash Varmane	31	**Bashkiria**	37	**Alkhanai**
	28	**Kislovodsk**	30	Pripyshma forests	32	Buzulukskii pine forest	38	Lower Kama
					33	Orlovskoe Polesie	39	Smolnyi
					34	**Pribaikalskii**	40	**Tunkinskii**
					35	Samara onion	41	**Shushenskii Bor**
					36	Sengileevskie mountains	42	**Samurskii**
Wildlife sanctuaries	43	Dzeren Valley	50	Tsasucheiskii pine forest	53	Agrakhanskii	56	Altacheiskii
	44	Stone steppe	51	Kirzinskii	54	Surskii	57	Beloozerskii
	45	Mekletinskii	52	Sarpinskii	55	**Tseiskii**	58	Voronezh
	46	Saratovskii					59	Krasnyi Yar
	47	Starokulatkinskii					60	Priazovskii
	48	Tsimlyanskii					61	Samurskii
	49	Harbinskii						

* Protected areas of mountain provinces, which contain steppe soils of low mountains, are indicated in bold.

In national parks, about 0.1% of the territory occupied by steppe soils and soil complexes in the country and 0.2% of the area of dry steppe and semidesert soils are preserved; in wildlife sanctuaries, it is 0.1 and 1.6%, respectively (Fig. 2b).

Currently, out of 31 cartographic units of soils and soil complexes of the steppe group throughout the country, 13 are represented in nature reserves; in national parks, 10 (of which b only two are new in relation to those already identified in reserves); and in wildlife sanctuaries, 11 (of which three are new in relation to those represented in nature reserves and two new ones in relation to nature reserves and national parks) (Figs. 2c, 2d). In total, federal protected areas represent 17 cartographic units of soils and soil complexes of the steppe group, and the typological representativeness is 55%. Of this amount, the majority of the diversity of soils and soil complexes is protected by nature reserves, 42% of the diversity of steppe soils in the country. National parks and wildlife sanctuaries, which are more than three times larger than nature reserves in area, increase the typological representativeness by only four legend units (13%; Figs. 2a, 2d).

Of the 24 soils and soil complexes of the group of dry steppes and semideserts identified on the territory of Russia, 13 soil varieties are represented in the reserves; in national parks, one soil (already present in nature reserves), and in wildlife sanctuaries, eight (of which two are new in relation to those protected in nature reserves). The reserves protect 54% of the typological diversity of the group of soils of dry steppes and semideserts throughout the country. National parks and wildlife sanctuaries are four times larger in area than nature reserves, but increase the typological representativeness by only 8% (Figs. 2a, 2c, 2d).

In general, modern federal protected areas preserve 58% of the typological diversity of steppe soils in Russia (including steppes, dry steppes, and semideserts). The core of soil diversity conservation is nature reserves: they occupy only a fifth of the total area of steppe protected areas, but provide protection for 47% of the diversity of steppe soils in the country, which is 81% of the diversity preserved in protected areas.

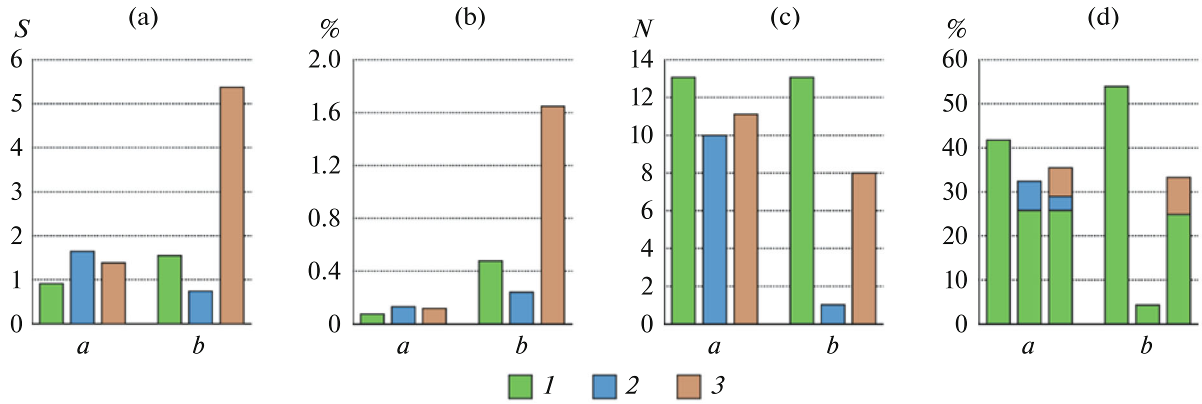

Fig. 2. Areal and typological representativeness of federal SPNA in relation to the diversity of steppe soils. (a) Area of steppe soils in protected areas (S, thousand km^2); (b) share of the area of steppe soils in protected areas (% of the area of soils of the corresponding group in the Russian Federation); (c) typological richness of soils in protected areas (*N*, number of units in the SMR key); (d) representativeness of the typological diversity of soils, provided by different categories of protected areas (% of the number of map units of the corresponding soil group). *Steppe soils: a*, group of steppe soils; *b*, group of dry steppe and semidesert soils. Federal protected areas: *1*, nature reserves; *2*, national parks; *3*, wildlife sanctuaries.

A more detailed analysis of cartographic information based on the SMR revealed the disproportionality of their areal representation within the federal-level protected areas. Particular attention is drawn to the discrepancy between the areas occupied by the main types of chernozems on the territory of the country and their protected representatives (Fig. 3). Such soils include typical chernozems, ordinary, southern; black soils, typical mycelial–carbonate (deep, slightly leached chernozems); southern and ordinary mycelial–carbonate chernozems (deep carbonate chernozems; according to WRB – Vermic/Calcic Chernozems (Pachic), Calcic Chernozems (Pachic). In the significant compact tracts of chernozems of the Ciscaucasia and southern Trans-Urals, there are no federal protected areas at all (Fig. 1).

An even greater discrepancy can be seen between the distribution of soils of dry steppes and semideserts in the country and in federal protected areas, despite the fact that the soils of this group in most cases occupy noticeably smaller areas than the soils of the steppes. The most significant array of soils of the group of dry steppes and semideserts not protected in protected areas is also located in Ciscaucasia; areas of soils actively used in agriculture are concentrated here: dark-chestnut micellar–carbonate (dark chestnut deep), chestnut mycelial carbonate (chestnut deep), light chestnut micellar carbonate (light chestnut deep; according to the WRB – Haplic Kastanozems, Calcic Kastanozems, Luvic Calcisols. (Fig. 3).

A number of less common steppe soils are also not represented in protected areas at the federal level, including, for example, meadow-chernozem–like soils, sometimes called Amur chernozems (according to WRB, Gleyic Phaeozems (Clayic)). The genesis of these unique powerful high-humus soils, the most arable soils of the Far East, is determined by a combination of specific conditions for their formation (monsoon climate, long-term deep seasonal freezing). Preservation of virgin varieties of such soils with corresponding ecosystems as standards is advisable from both a scientific and a practical point of view.

Thus, the analysis showed that, at present, natural variants of many steppe soils in the country, including some of the most fertile ones, widely used in agricultural production, are not represented in federal protected areas (Fig. 3).

Opportunities for increasing the representation of soil diversity in the PA system. The most significant compact array of soils not represented in federal protected areas is located in Ciscaucasia. The largest territory here falls on one cartographic unit, southern and ordinary mycelium–carbonate chernozems (deep carbonate chernozems), the area of which in this country reaches 98000 km^2 (7.9% of the area of all soils of the steppe group and 42.9% of the area of soils of this group not represented in federal protected areas). The entire area of distribution of these soils has been significantly changed by agricultural activity. There are no significant areas with virgin soils and plant associations left in the region. Despite the fact that small isolated areas cannot fully perform the functions of nature standards, their reserve, resource conservation, and monitoring role is manifested to the maximum extent in areas that have been strongly modified by anthropogenic impact; therefore, an inventory of even the small areas of undisturbed soils under natural soil or regenerating vegetation is required here. First of all, it is logical to focus on regional protected areas with minimally disturbed biogeocenoses. It should be borne in mind that, in most cases, there is no information about the soil cover of regional protected areas.

A preliminary analysis of the available information showed that, within the distribution area of southern

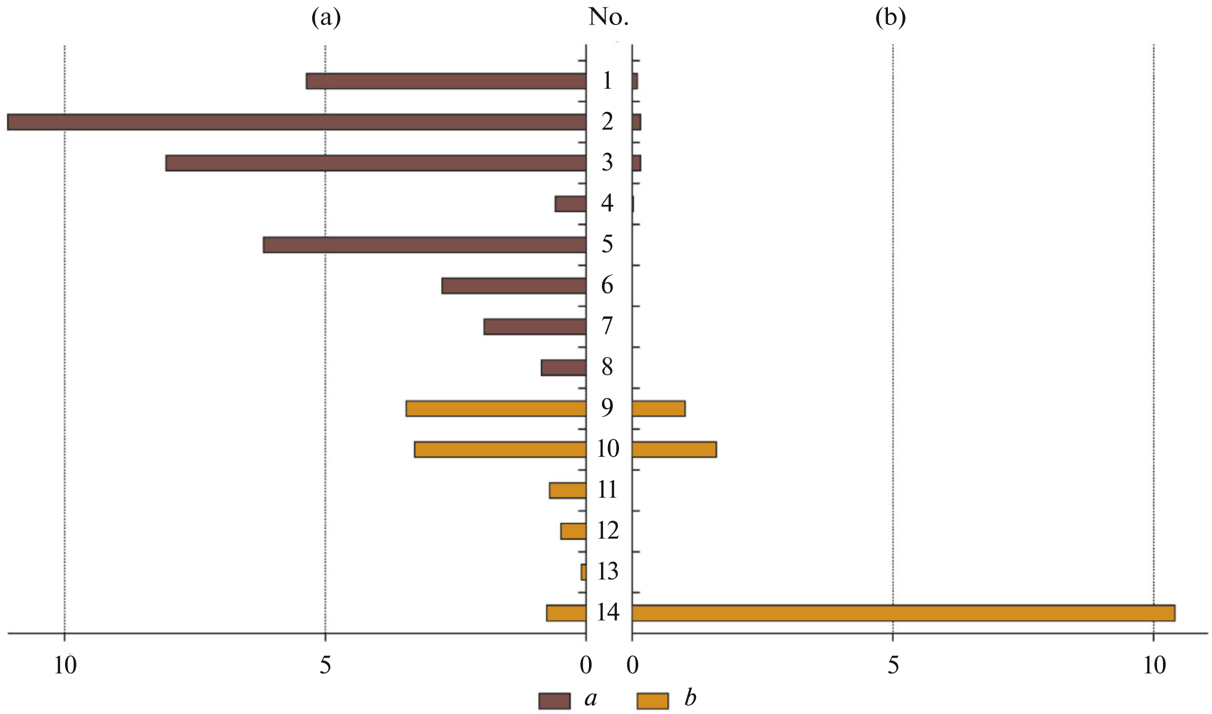

Fig. 3. Distribution of some steppe soils in the Russian Federation and their representation in federal protected areas. (a) Area occupied by soil, % of the total area of soils in steppes, dry steppes, and semideserts; (b) share of soil area within protected areas, % of the total area of this soil on the territory of Russia. *Steppe soils: a*, group of steppe soils; *b*, group of dry steppe and semidesert soils. *No. of soils:* 1, Haplic/Vermic Chernozems; 2, Calcic Chernozems; 3, Calcic Chernozems; 4, Vermic/Calcic Chernozems (Pachic); 5, Calcic Chernozems (Pachic); 6, Luvic Chernozems (Tonguic); 7, Calcic Chernozems (Tonguic); 8, Calcic Chernozems (Tonguic); 9, Haplic Kastanozems; 10, Gypsic Kastanozems; 11, Haplic Kastanozems; 12, Calcic Kastanozems; 13, Luvic Calcisols; 14, Calcic Kastanozems.

and ordinary mycelial–carbonate chernozems, there are 66 protected areas of regional significance, of which intact types of these soils can be represented in eight protected areas in Rostov oblast, two in Krasnodar krai, and six in Stavropol krai (Fig. 4).

Studies of the soil cover of regional protected areas in Rostov oblast showed that the upland areas of two protected areas, where these soils were represented, have been deprived of their protective status since 2017 and are plowed up; i.e., protected areas have been preserved with the same names, but their area has been reduced to a few tens of hectares due to the destruction of upland areas. Currently, southern and ordinary mycelial–carbonate chernozems are found only in three regional protected areas of Rostov oblast (Bezuglova et al., 2022). No special surveys of soil cover have been carried out in regional protected areas of Krasnodar krai and Stavropol krai.

Apparently, when searching for minimally disturbed representatives of southern and ordinary mycelial–carbonate chernozems, it is advisable to first of all focus on areas with the best-preserved steppe ecosystems of this region. For example, a site in the southwestern part of the Stavropol Upland (Uspenskaya steppe) has been proposed for conservation; here, on an area of about six thousand hectares, steppe ecosystems have been preserved (Chibilev, 2022, 2018) and, according to our estimates, natural variations in the southern and ordinary micellar-carbonate chernozems (WRB – Calcic Chernozems (Pachic)) can be found. Within the Taman, North Stavropol, and Prikumskii areas, dark chestnut, chestnut and light chestnut micellar-carbonate (deep) soils can be found (WRB – Haplic Kastanozems, Calcic Kastanozems, Luvic Calcisols)), also currently not represented in federal protected areas. At the same time, as noted by A.A. Chibilev (2022), there is a need for targeted work on the justification and design of new protected areas or the transformation of existing regional protected areas into federal ones. Let us also add that soil surveys should be a mandatory part of such work.

Thus, at present there is a real threat of loss of the last virgin representatives of the highly fertile typical of the Ciscaucasia mycelial-carbonate chernozems and chestnut soils. To date, the total area of all areas of undisturbed or minimally disturbed representatives of southern and ordinary mycelial–carbonate chernozems does not exceed several hundred hectares, despite the fact that their total area in the country reaches 98000 km^2. A similar situation occurs with some of the other soils listed above. Detection of even small areas of such soils, at least as samples for com-

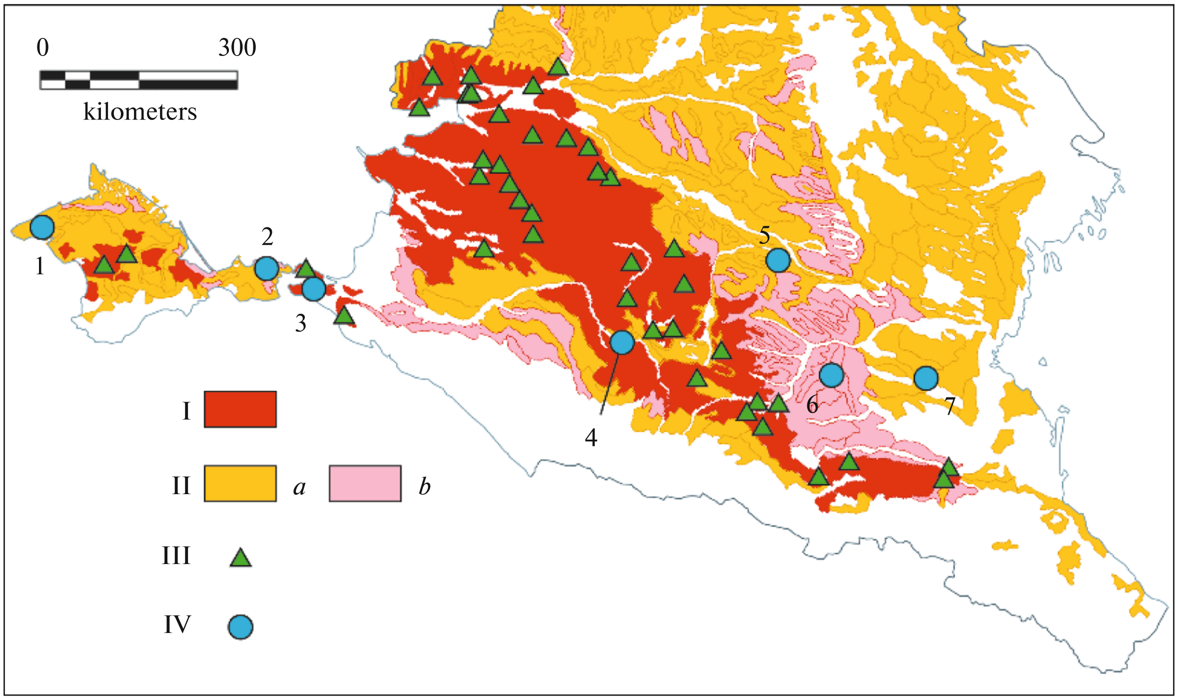

Fig. 4. Areas of steppe soils not represented in federal SPNA and the location of currently existing regional PAs and possible locations of new protected areas. I, Area of Calcic Chernozems (Pachic); II, soils and soil complexes of steppes, dry steppes, and semideserts: (*a*) found in federal protected areas, (*b*) not found in federal protected areas; III, regional PAs; IV, possible locations of new steppe SPNA (Chibilev, 2018): 1, Tarkhankutskii; 2, Kerch; 3, Tamanskii; 4, Assumption steppe; 5, North Stavropol; 6, Prikumskkii, 7, Nogai steppe.

parison with anthropogenically modified analogues, requires special study. It is necessary to inventory the areas of their distribution, as well as to optimize the boundaries and increase the protection status of the most representative protected areas at the regional level.

CONCLUSIONS

Using geoinformation analysis methods, we assessed the areal and typological representation of the natural diversity of steppe soils in Russia in the system of specially protected natural areas based on the vector Soil Map of Russia on a scale of 1 : 2500000 (a combined version of the Soil Map of the RSFSR and the Soil Map of Crimea). The analysis was carried out separately for two groups of soils and soil complexes: “Soils of the steppes” and “Soils of dry steppes and semideserts.” We revealed a low areal representativeness of federal SPNA in relation to both of these groups of soils, noticeably lower compared to other large groups of soils in Russia. Many SPNA in the steppe regions are confined to intrazonal positions: floodplain and ravine landscapes, wetlands, outcrops of atypical soil-forming rocks, etc.; therefore, steppe soils are not found in them at all.

An assessment of typological representativeness at the scale and level of consideration of the SMR showed that less than 60% of the natural diversity of steppe soils in Russia is preserved in federal PA. Most of the conservation of steppe soil diversity is provided by nature reserves, which account for only a fifth of the total area of steppe SPNA. Of the 31 typological divisions of soils of the steppe group throughout the country, 13 (42%) are represented in reserves, ten are represented in national parks (of which two are new in relation to those represented in reserves), and in wildlife sanctuaries, there are 11 (of which three are new in relation to the diversity soils of reserves and two are new ones in relation to those represented in reserves and national parks), i.e., national parks and wildlife sanctuaries, which are more than three times larger than nature reserves in area, increase the typological representativeness of the federal system of protected areas by only four divisions of the legend (13%). Of the 24 typological units of soils and soil complexes of dry steppes and semideserts throughout the country, 13 (54%) are represented in nature reserves, one in national parks, and eight in wildlife sanctuaries. National parks and wildlife sanctuaries, which are four times larger in area than nature reserves, increase the typological representativeness by only 8%.

Thus, at present, natural variants of many of the steppe soils of the country, including some of the most fertile ones that are widely used in agricultural production, are not represented in federal SPNA. The most significant compact array of such soils in terms of area is located in the Ciscaucasia. The largest territory here falls on one cartographic unit—the southern and ordinary mycelial–carbonate chernozems (deep carbonate chernozems), almost completely plowed; dark chestnut mycelial-carbonate (deep dark chestnut), chestnut mycelial-carbonate (deep chestnut) and light chestnut mycelial-carbonate (deep light chestnut) soils occupy slightly smaller areas and experience a high pasture load. Preservation of virgin examples of such soils, at least as samples for comparison with anthropogenically modified analogues, requires an immediate inventory of all areas of their distribution, conducting special studies, and assigning them a protection status.

Summarizing the main results obtained, we can draw the following conclusions:

(1) The total area of steppe soils in Russia (including steppes, dry steppes, and semideserts) reaches 1564000 km^2, 9.4% of the country's soil area, of which 7.4% is attributable to the actual steppes and 2.0%, to dry steppes and semideserts. In SPNA they occupy 11500 km^2 and are found in 23 nature reserves, 14 national parks, and 13 wildlife sanctuaries in Russia. Of the 61 federal SPNA located in the steppe regions, in 20 steppe soils are not represented or occupy less than 5% of the area.

(2) A low areal representation of steppe soils and soil complexes in SPNA was revealed, which was especially pronounced for state reserves. The representation of soils of the steppe group in all federal SPNA is less than 0.5%, the group of dry steppes and that of semideserts is about 2%; in state reserves, it is 0.07% and less than 0.5%, respectively.

(3) It is shown that, out of 55 cartographic units of steppe soils available on the territory of Russia (including steppes, dry steppes, and semideserts), 58% are represented in federal SPNA, and reserves, occupying a fifth of the total area of steppe SPNA, protecting 47% of the typological diversity of steppe soils in the country, which accounts for 81% of the diversity, represented in the SPNA. Currently, natural variants of many of the country's steppe soils, including some of the most fertile ones that are widely used in agricultural production, are not represented in federal protected areas.

(4) The square footage of the most significant area of soils not represented in SPNA—southern and ordinary mycelial–carbonate chernozems—reaches 98000 km^2 (7.9% of the area of all soils of the steppe group and 42.9% of the area of soils of this group not represented in federal SPNA). Apparently, to date, the total square footage of all areas of undisturbed or minimally disturbed examples of these soils does not exceed several hundred hectares.

(5) Currently, there is a real threat of losing the last virgin examples of highly fertile soils typical of Ciscaucasia: southern and ordinary mycelial–carbonate chernozems; dark chestnut, chestnut, and light chestnut mycelial carbonate soils. Preservation of virgin examples of such soils, at least as samples for comparison with anthropogenically modified analogues, requires an immediate inventory of all areas of their distribution, conducting special studies, and assigning them a protection status.

FUNDING

This work was supported by the Russian Science Foundation, project no. 22-14-00107, of Moscow State University, as well as within the framework of a State Assignment, project no. AAAA-A18-118042490060-1, of the Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, and project no. 122041200035-2, of the Institute of Fundamental Problems of Biology, Russian Academy of Sciences.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This work does not contain any studies involving human and animal subjects.

CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

REFERENCES

Abaturov, B.D., Comparative productivity of forest and grass ecosystems, *Her. Ross. Akad. Nauk*, 2023, vol. 93, no. 2, pp. 127–134.

Amundson, R., Are soils endangered? in *The Earth Around Us: Maintaining a Livable Planet*, Schneiderman, J., Ed., New York: WH Freeman, 2000, pp. 144–153.

Bezuglova, O.S., Gorbov, S.N., Litvinov, Yu.A., and Chernova, O.V., *Printsipy sozdaniya Krasnoi knigi pochv Rostovskoi oblasti* (Principles for Creating the Red Book of Soils of the Rostov Oblast), Rostov-on-Don: Yuzhnyi Feder. Univ., 2022.

Chernova, O.V., Conservation of virgin soils' diversity in network of nature reserves of the Russian Federation, *Izv. Ross. Akad. Nauk, Ser. Geogr.*, 2012, no. 2, pp. 30–37.

Chernova, O.V., Ryzhova, I.M., and Podvezennaya, M.A., Historical trends in the amount and structure of organic carbon stocks in natural and managed ecosystems in European Russia, in *IOP Conf. Ser.: Earth Environ. Sci.*, 2020, vol. 438. https://doi.org/10.1088/1755-1315/438/1/012005

Chibilev, A.A., Border Russian-Kazakh landscape transects as elements of the macroregional ecological network of Northern Eurasia, *Voprosy Stepevedeniya*, 1999, no. 1, pp. 13–20.

Chibilev, A.A., Prospects for the development of the continuous network of key natural reserves in the steppe European Russia based on connected analysis of modern landscape structure, *Voprosy Stepevedeniya*, 2018, no. 14, pp. 36–44.

Chibilev, A.A., The landscape and ecological framework as a territorial basis for stable development in Russia's agricultural regions, *Yug Rossii: Ekologiya, Razvitie*, 2022, vol. 17, no. 2 (63), pp. 115–121.

Chibilev, A.A., Sokolov, A.A., and Rudneva, O.S., On the efficiency of natural agro-potential use in the steppe regions of European Russia, *Izv. Ross. Akad. Nauk, Ser. Geogr.*, 2019, no. 4, pp. 24–30.

Chibilev, A.A., Petrishchev, V.P., and Kosykh, P.A., Analysis of the geographical factors of sustainable development of municipalities in the south of the Urals and western Siberia, *Yug Rossii: Ekologiya, Razvitie*, 2021, vol. 16, no. 4 (61), pp. 113–126.

Daily, G.C., Developing a scientific basis for managing earth's life support systems, *Conserv. Ecol.*, 1999, vol. 3, no. 2, art. 14. http://www.consecol.org/vol3/iss2/art14. Cited July 11, 2023.

Dobrovol'skii, G.V. and Nikitin, E.D., *Funktsii pochv v biosfere i ekosistemakh. Ekologicheskoye znacheniye pochv* (Functions of Soils in the Biosphere and Ecosystems. Ecological Significance of Soils), Moscow: Nauka/Interperiodika, 1990.

Dobrovol'skii, G.V., Chernov, I.Yu., Bobrov, A.A., Dobrovol'skaya, T.G., Lysak, L.V., Onipchenko, V.G., Gongal'skii, K.B., Zaitsev, A.S., Terekhova, V.A., Sokolova, T.A., Terekhin, V.G., Shmarikova, E.V., and Chernova, O.V., *Rol' pochvy v formirovanii i sokhranenii biologicheskogo raznoobraziya* (The Role of Soil in the Formation and Conservation of Biological Diversity), Moscow: KMK, 2011.

Gulyanov, Yu.A. and Chibilev, A.A., Ecologization of steppe agrotechnologies in the conditions of natural and anthropogenic environmental changes, *Theor. Appl. Ecol.*, 2019, no. 3, pp. 5–11.

Ibàñez, J.J., De-Alba, S., Bermúdez, F.F., and García-Álvarez, A., Pedodiversity: Concepts and measures, *Catena*, 1995, vol. 24, pp. 215–232.

Klassifikatsiya i diagnostika pochv Rossii (Classification and Diagnostics of Soils in Russia), Smolensk: Oikumena, 2004.

Natsional'nyi atlas pochv Rossiiskoi Federatsii (National Soil Atlas of the Russian Federation), Shoba, S.A., Alyabina, I.O., Urusevskaya, I.S., and Chernova, O.V., Eds., Moscow: Astrel', AST, 2011.

Orlova, I.V., Dynamics and balance of the land use structure in the border steppe regions of Western Siberia, *Stepnoi Bull.,* 2006, nos. 21–22, pp. 45–50.

Pochvennaya karta RSFSR. Masshtab 1 : 2500000 (Soil Map of the RSFSR. Scale 1 : 2500000), Fridland, V.M., Ed., Moscow: *Glavn. Upravl. Geodez. Kartogr.*, 1988, digital version, 2007.

Prisyazhnaya, A.A., Khrisanov, V.R., Mitenko, G.V., Chernova, O.V., and Snakin, V.V., The analysis of a soil diversity of nature reserves and national parks of Russia (new territories), *Geodez. Kartogr.*, 2016, no. 12, pp. 7–15.

Romanenko, G.A., Komov, N.V., and Tyutyunnikov, A.I., *Zemel'nye resursy Rossii, effektivnost' ikh ispol'zovaniya* (Land Resources of Russia, Efficiency of Their Use), Moscow: Rossel'khozakad., 1996.

Soil Data Center of Lomonosov Moscow State University, 2024. https://soil-db.ru/map?lat=45.0404&lng=36.7987&zoom=7. Cited September 2, 2023.

Specially Protected Natural Areas of Russia, 2024. http://oopt.aari.ru/. Cited August 2, 2023.

Tishkov A.A. and Nekrich A.S., Factors of territorial differentiation of the agricultural landscape and prospects for the preservation of steppes in Belgorod Oblast, *Arid Ecosyst.*, 2022, vol. 12, no. 2, pp. 131–141.

Tishkov, A.A., Belonovskaya, E.A., Zolotuhin, N.I., Titova, S.V., Tsarevskaya, N.G., and Chendev, Yu.G., Preserved sections of steppes as the basis for the future ecological framework of Belgorod Oblast, *Arid Ecosyst.*, 2020, vol. 10, no. 1, pp. 36–43.

Tishkov, A.A., Belonovskaya, E.A., and Titova, S.V., Steppes and meadows in the review "Temporary grasslands and shrublands of Russia" (2020), *Voprosy Stepevedeniya*, 2021a, no. 1, pp. 21–47.

Tishkov, A.A., Krenke, A.N., Titova, S.V., Yermokhin, M.V., Levykin, S.V., Karavaev, V.A., Kozlova, A.A., Kuricheva, O.A., and Bukvareva, E.N., Variations in the aboveground phytomass in Northern Eurasia in the 21st century, *Dokl. Earth Sci.*, 2021b, vol. 497, no. 2, pp. 348–353.

Urusevskaya, I.S., Alyabina, I.O., and Shoba, S.A., The 1 : 8000000 Soil-ecological zoning map of the Russian Federation. Scale 1 : 8000000, 2019a. https://files.soil-db.ru/files/soil-ecological-zoning-map.pdf. Cited September 2, 2023.

Urusevskaya, I.S., Martynenko, I.A., and Alyabina, I.O., *Pochvennaya karta Kryma. Masshtab 1 : 2500000. Vrezka k "Karte pochvenno-ekologicheskogo raionirovaniya Rossiiskoi Federatsii", masshtab 1 : 8000000* (The 2500000 Soil Map of Crimea. Inset to the 8000000 Soil-Ecological Zoning Map of the Russian Federation"), Moscow: Mosk. Gos. Univ., 2019b.

Publisher's Note. Pleiades Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.