FORESTRY IDEAS, 2022, vol. 28, No 1 (63): 268–279

ON THE RELICT OF THE FLORA IN INSULAR PINE FORESTS IN THE RUSSIAN PLAIN

Nataliya O. Kin

Landscape Ecology Department, Steppe Institute, Ural Branch of the Russian Academy of Sciences, Orenburg, 460000, Russia. E-mail: kin_no@mail.ru

Received: 03 February 2022 Accepted: 27 June 2022

Abstract

The forests, located in the conditions of steppe and forest-steppe zones, represent insular massifs with an extrazonal type of vegetation. Based on the unanimous opinion of scientists about the origin of insular pine forests and the assumption that pine forests in the past formed a single array with the zonal northern taiga, the concept of relict flora of insular pine forests arose. Scientists note that, despite the high degree of steppe species, the core of the flora is boreal in nature. The purpose of the study was to test the assumption of the relict nature of flora found in insular pine forests in the Russian Plain in contemporary conditions based on the analysis of the spectrum of latitudinal groups. We have studied the flora of the pine forests in the Russian plain: Usmansky and Khrenovskoy – located in the subzone of the typical forest-steppe of the Oka and Don Rivers lowland; Buzuluksky and Krasnosamasrky – occupying an area in the steppe zone of the Volga region. The flora of the forests in the steppe and forest-steppe zones fully reflects the natural and climatic features of these areas, which is clearly visible in the spectra of the latitudinal groups of the studied flora. One-third of the species in the floristic core are forest groups, which confirms the previously stated assumptions about the relict nature of insular pine forests. This was also confirmed by the analysis of the spectrum of latitudinal groups of rare species in the flora. In the floristic core, among the rare ones, there was a high percentage of forest species that determine its forest character. The data obtained also indicate that for many steppe and forest-steppe regions, forests may be the only habitats of forest species. For example, *Drosera rotundifolia* L., *Calla palustris* L., *Lycopodium annotinum* L., and *Neottianthe cucullata* (L.) Schlehter.

Key words: floristic core, rare species, spectrum of latitudinal groups, steppe and forest-steppe zone.

Introduction

Pine forests are insular forests, where the main forming species is Scots pine occurring at the southern limit of distribution. Located in the steppe and forest-steppe zones along the left bank of rivers, pine forests represent an extra-zonal type of vegetation. They can stretch along the riverbeds from the taiga to the steppe zone, forming ribbon massifs, but in most cases, they are compact forest massifs.

Most scientists share the same opinion about the origin of the insular pine forests. According to them, the periodic Quaternary glaciations covered different areas and alternated with warming stages, and thus had a significant influence

on the formation of flora (Gerasimov and Markov 1939, Markov and Velichko 1967). The vegetation cover changed repeatedly under the influence of glacial dynamics. In the interglacial epochs during the melting of glaciers, troughs of ancient flow along the ancient riverbed were formed, on the bottoms of which there was an accumulation of ancient alluvial sand sediments, then rewetted. Pine trees settled on the deposited sands (Gvozdetsky 1968, Kazmin 2017).

The assumption that the pine forests, located in the depth of the steppe zone, in the past constituted a single massif merging with the zonal northern taiga, was suggested by Gordyagin (1897), on the example of the insular pine forests of Kazakhstan. His concept provided an explanation for the occurrence of some taiga and marsh plants. Later this concept was supported and developed by Krasheninnikov (1939), Pavlov (1948), Gribanov (1960) and other scientists. Gorchakovsky (1987), studying the flora of pine massifs in low mountains of the Kazakh small knoll topograph, noted that despite its high degree of steppification, the core of the flora is of boreal character. This provoked high botanical and geographical interest and provided grounds for the development of the concept of relict nature of flora in pine forests.

The history of the pine forests of the Russian Plain can be dated back to the late Pleistocene to the Holocene (Kremenetsky et al. 1998). The last blanket glaciation in the Late Pleistocene (Valdai) covered only the northwestern part of the Russian Plain; the areas where the studied pine forests are currently located were far from the boundaries of blanket ice in the periglacial zone. Nevertheless, the climate changes that occurred repeatedly throughout the Valdai time were reflected in the vegetation cover of the entire plain and beyond. During humid periods, boreal floristic complexes were more widespread. During the increasing aridization of the territory, periglacial, almost treeless spaces were actively formed, the vegetation cover of which was composed of species that are currently representatives of different zonal floristic complexes: boreal, nemoral steppe, desert-steppe. As a result of climate fluctuations, the ratio and role of these floristic complexes in the vegetation cover changed, alternately shifting from the dominant to the subordinate position and vice versa (Agafonov 2006).

According to the spore-pollen analyses carried out in the territories of modern bogs, there were few tree species in the Late Valdai time, and the vegetation cover was represented by cold dry steppes, dominated by species of Chenopodiaceae family (Agafonov 2006) and species of the genus *Artemisia* (Kremenetsky et al. 1998).

In the Holocene the climatic conditions changed towards softening, birch and pine actively penetrated into the river valley and spread over sandy terraces. This led to the formation of pine forests with an admixture of birch. From this time, the history of pine forests can be counted. In the Holocene pre-boreal period, the boreal floristic complex with the dominance of pine with an admixture of spruce and birch in the island massifs still prevails. Later on, the boreal floristic complex is confidently replaced by the desert-steppe floristic complex. The most powerful migration waves of steppe and desert species from the south and southeast occurred during the Atlantic Holocene (Agafonov 2006). Thus, the forest massifs dominated by *Pinus sylvestris* that emerged at the beginning of the Holocene underwent significant changes and are currently represented in the Russian Plain by compact island massifs in the steppe

and forest-steppe zones.

In the development of modern flora, in addition to the paleogeographical factor that determines the events of past years, the modern abiotic factor is taken into account, which makes it possible to state the features of the current state of the flora and predict its further development. Also, the most dynamic - anthropogenic factor, capable of fundamental changes in the landscape both as a whole and its individual components, is becoming increasingly important.

The forest ecosystems of the European part of the continent have been significantly destroyed as a result of human activity, which has led to a decrease in the forested area and the emergence of natural-anthropogenic complexes. However, scientists in many European countries are finding remaining forest areas that have a distinct identity and continue to play a vital ecological role in maintaining a habitat for biodiversity. Most often, these natural islands are the only habitat for many endangered species. One of these unique ecosystems are the island pine forests of the Russian Plain.

Modern scientists (Agafonov 2006, Chibilev 2008, Korchikov et al. 2009, Kliment'ev 2010, Matveev et al. 2012) note a change in the structure of the pine forests of the Russian Plain, expressed in a decrease in the area of natural forest tracts. This is primarily due to numerous fires and uncontrolled logging. Thus, in the pine forests of the Russian Plain located in the forest-steppe zone, natural pine forests account for less than half of the area of woodlands (Matveev et al. 2012).

The pine forests of the Russian Plain of the steppe zone, located in more extreme forest-growing conditions, have also historically experienced a powerful anthropogenic load, which led them to complete fragmentation (Pallas 1809, Darkshevich 1953, Chibilev 2008, Kliment'ev 2010). The connection between the pine forests has been preserved in floodplain forests, which have become ecological corridors for forest biota (Korchikov et al. 2009).

Modern researchers of the pine forests flora noted their floristic richness and diversity (Starodubtseva 1999, Grigorievskaya 2004, Kin 2009, Korchikov et al. 2009, Kin et al. 2012, Saxonov et al. 2012, Seregin 2015), indicating that these forests still remain unique natural landscapes.

In this regard, there is a hypothesis about the preservation of the relict nature of the flora of the pine forests despite the change in environmental conditions. To establish the validity of this hypothesis, we will rely on the opinion of Gorchakovsky (1987). He pointed out that the relict nature of the flora of the in low mountains of the Kazakh small knoll topograph, forest directly depends on the presence of boreal (in a broad sense) species in the core of the studied flora. The purpose of our work is to reveal the relict nature of the island forests that occur across the Russian Plain.

Materials and Methods

We carried out an inventory of the flora of the pine forests of the Russian Plain: Usmansky, Khrenovskoy, Buzuluksky, and Krasnosamarsky (Fig. 1).

In physiographic terms, the Usmansky and Khrenovskoy pine forests are located in the typical forest-steppe subzone of the Oka and Don Rivers lowland of the central part of the Russian plain (Milkov 1977). The Usmansky pine forest (51°41' – 52°02' N, 39°21' – 39°47' E) is located in the forest-steppe zone along the

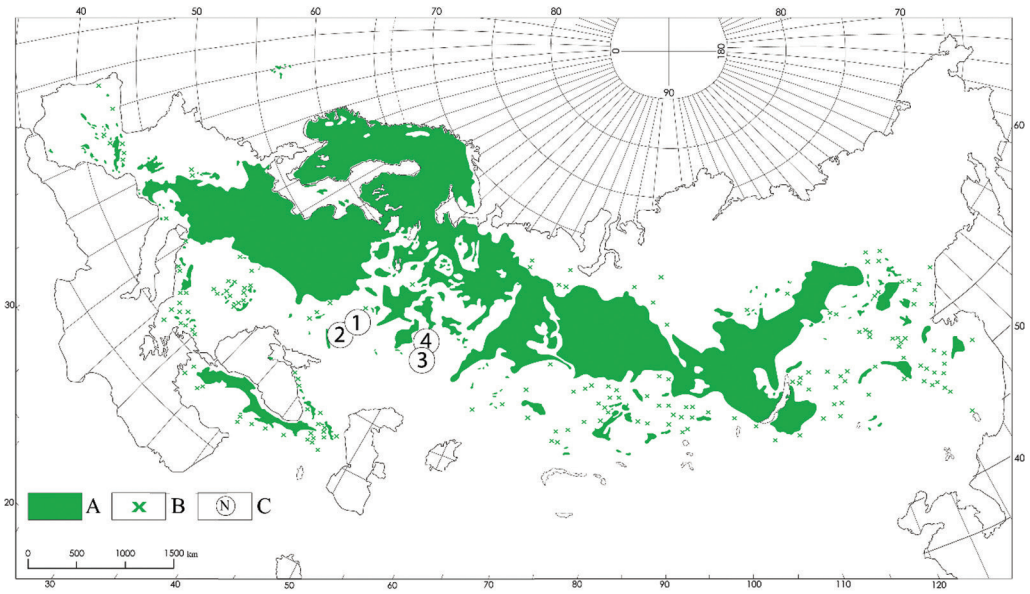

Fig. 1. Schematic map of the studied Scots pine forests location (Crichfield and Little 1966, in the authors' version).

Legend: A – Main range of *Pinus sylvestris* L.; B – Areas separated from the main range of *Pinus sylvestris*; C – Studied pine forests (1 – Usmansky, 2 – Khrenovskoy, 3 – Buzuluksky, 4 – Krasnosamarsky).

watersheds of the Voronezh and Usman rivers in Voronezh and Lipetsk regions. The total area is 70,700 ha (covered by forest – 63,100 ha), the reserve occupies 31,053 ha. Khrenovskoy pine forest is located on the left bank of the Bityug River (51°05' – 51°16' N, 40°06' – 40°25' E), on the border of steppe and forest-steppe zones in Voronezh oblast. The area of the Khrenovskoy pine forest is 40,210 ha. Buzuluksky and Krasnosamarsky pine forests are located in the southeastern part of the Russian Plain (Fig. 1), occupying a vast area in the western part of the Obshchesyrtovsko-Preduralskaya upland steppe province, in the steppe zone of Zavolzhye (Godnev et al. 1949). Buzuluksky pine forest is located between 52°53' – 53°19' N and 51°05' – 52°31' E within the Orenburg and Samara regions. Considering the numerous small isolated wood patches, the total area of the Buzuluk pine forest is about 350,000 ha.

The Krasnosamarsky pine forest (52°58' – 53°05' N and 50°59' – 51°07' E) is situated in the south-east of the Samara Region in the right-bank part of the valley of the middle course of the Samara River.

Krasnosamarsky pine forest occupies an area of 13,554 ha, including 1565 ha in the Samara river floodplain and 12,286 ha outside the floodplain, and the total area of the Krasnosamarsky forest together with open meadow and steppe areas is about 30,000 ha.

In the pine forests under study, there is an increase in continentality from the west (Usmansky and Khrenovskoy pine forests) to the east (Buzuluky and Krasnosamarsky pine forests), which manifests itself in the deterioration of hydrothermal conditions and other parameters (Table 1).

Table 1. Indicators of temperature regime and precipitation for the studied pine forests.

Pine forests	Average annual air temperature, °C	T_{max}, °C	T_{min}, °C	Amplitude, °C	Average annual precipitation, mm
Usmansky	+5.3	+38.9	-41.8	80.7	653
Khrenovskoy	+5.8	+35.0	-41.0	76.0	527
Buzuluksky	+3.6	+48.0	-50.0	98.0	530
Krasnosamarsky	+4.5	+41.0	-49.0	90.0	359

Note: T_{max} and T_{min} are absolute maximum and minimum temperatures.

Increasing aridization of the climate is also reflected in the taxonomic structure of pine forests (Kin et al. 2020). The floras of Usmansky and Khrenovskoy pine forests, located in more favorable climatic conditions, are represented by a large number of families, genera, and species, compared to the floras of Buzuluksky and Krasnosamarsky pine forests, located in extreme conditions for forest ecosystems (Table 2).

Table 2. Taxonomic diversity of higher plants in the studied pine forests.

Pine forests	Number				
	Families	Genera	Types		
			Indigenous	Alien	Introducers
Usmansky	123	508	852	219	12
Khrenovskoy	108	430	718	130	2
Buzuluksky	101	383	675	112	7
Krasnosamarsky	93	352	591	80	3

Species found in all floras pine forests are involved in the formation of the floras core.

It was noted that a part of species for some pine forests is indigenous and for others it is a part of alien fraction. Therefore, when counting taxa of the aboriginal and alien fraction of the pine forests of flora, only those that have the same origin for all the studied pine forests were considered.

The species involved in the formation of the floristic core of the studied pine forests are distributed by latitudinal geographical groups (Kulikov 2005). In order to establish the relict nature of the flora of pine forests, special attention was given to the 'boreal species in the broad sense', which are the species composing the boreal, boreo-nemoral, boreo-nemoral forest-steppe and nemoral groups. All they were classified in our work under the general name 'forest'.

Results and Discussion

It was found that 419 species from 281 genera of 89 families participate in the formation of the floristic core. The nucleus of the aboriginal fraction of the flora consisted of 358 species from 236 genera of 84 families. The core of the adventive fraction of the flora includes 25 families, 41 genera, and 44 species.

Obviously, the basis of the floras of the studied pine forests is formed by the aboriginal fraction. Considering this fraction of

the studied floras in the latitudinal spectrum, we revealed that almost one third of the species belong to the plurizonal group (Table 3). Otherwise, the order of the groups is individual for each of the studied floras. In the Usmansky pine forest, the boreo-nemoral group is second in the number of species, while the forest-steppe and steppe groups contain fewer species. In the flora of the other three pine forests, on the contrary, the forest-steppe and steppe group are richer in species and take second place in this ranking, leaving the boreonemoral group in a lower position.

In the Usmansky pine forest, the complex of latitudinal groups represented by forest species occupied the middle position in the spectrum and corresponded to 4–6 positions, in descending order: boreonemoral forest-steppe, nemoral, boreal. Forest-steppe, steppe groups are few in number. The smallest number of species belonged the nemoral forest-steppe and nemoral forest-steppe and steppe groups.

In the flora of the Khrenovskoy pine forest, only three groups with forest species wre highly significant, occupying 3–5 positions in the spectrum, in descending order: boreaonemoral, boreonemoral forest-steppe, nemoral. Boreal is the smallest of all groups. It occupies the last place in the spectrum, yielding by the number of species to steppe, forest-steppe, nemoral forest-steppe, and nemoral forest-steppe and steppe groups (Table 3).

The nature of the Buzuluksky pine forest flora is peculiar. Having a large area and a variety of landscapes, the pine forest forms favorable conditions for species belonging to different latitudinal groups. The forest character of the pine forest is also noticeable in the

Table 3. Spectrum of latitudinal groups of the native fraction of the flora of pine forest and the floristic core.

Name of groups	I. Total species, number/%				II. Species in the core, number/%			
	1	2	3	4	1	2	3	4
Boreal	64/7.5	33/4.6	36/5.5	16/2.7	9/14.0	9/27.3	9/25.0	9/56.2
Boreonemoral	122/14.3	89/12.4	96/14.2	65/11.0	46/37.1	46/51.7	46/47.9	46/70.8
Boreonemoral forest-steppe	69/8.1	57/7.9	61/9.0	46/7.8	33/47.8	33/57.9	33/71.7	33/71.7
Nemoral	66/7.7	55/7.7	41/6.1	28/4.7	19/28.8	19/34.5	19/46.3	19/67.8
Nemoral forest-steppe	40/4.7	35/4.9	26/3.9	21/3.6	15/38.5	15/ 42.8	15/57.7	15/71.4
Nemoral forest-steppe and steppe	37/4.3	35/4.9	30/4.4	27/4.6	22/61.1	22/62.8	22/73.3	22/81.5
Forest-steppe	54/6.3	43/6.0	22/3.3	22/3.7	12/22.6	12/27.9	12/27.3	12/54.5
Forest-steppe and steppe	99/11.6	94/13.1	102/15.1	115/19.5	56/56.6	56/59.6	56/54.9	56/48.7
Steppe	54/6.3	51/7.1	67/9.9	83/14.0	17/31.5	17/33.3	17/25.4	17/20.5
Plurizonal	247/29.0	226/31.4	193/28.6	168/28.4	129/52.9	129/57.3	129/66.8	129/76.8
Species in total	852	718	674	591	358	358	358	358

Note: 1 – Usmansky; 2 – Khrenovskoy; 3 – Buzuluksky; 4 – Krasnosamarsky pine forest.

spectrum, where the boreonemoral group keeps the third position by the number of species, and the boreonemoral forest-steppe, nemoral and boreal groups occupy 5th to 7th lines of the rating. Zonal location had a noticeable influence on the development of boreal flora. Here a significant number of species fall in the steppe group, which occupied the 4th position in the ranking. The least number of species (in descending order) belonged to the nemoral forest-steppe, nemoral forest-steppe and steppe, as well as forest-steppe groups (Table 3).

In the flora of the Krasnosamarsky pine forest, the steppe group was among the top three in terms of the number of species, followed by the boreonemoral, boreonemoral forest-steppe and nemoral groups. The boreal group contained the smallest number of species. A little more species were observed in the nemoral forest-steppe and steppe, forest-steppe and nemoral forest-steppe groups.

The spectrum of the latitudinal groups of the floristic core differed from the studied floras, with the exception of the first three leading groups in terms of the number of species, and the leading ones in the structure of flora (Table 3). Here a significant part of the species belonged to the plurizonal group – 36.0 %. This group consisted of species that have a wide distribution and are found in almost all zones. This includes a large number of weed species (apophytes), among which: *Tripleurospermum inodorum* (L.) Sch.-Bip., *Chenopodium album* L., *Erysimum hieracifolium* L. Also, in this group there were many representatives of aquatic flora: *Stratiotes aloides* L., *Nuphar lutea* (L.) Smith, *Sparganium emersum* Rehm. More than 2 times less, relative to the leading one, representatives of the forest-steppe and steppe (15.6 %) groups entered the floristic core. The species composing this group were found in ecosystems transitional between forest and steppe – forest-steppe zone and spread further south, finding habitats in the steppe zone, for example, species of the genus *Artemisia*: *A. abrotanum* L., *A. austriaca* Jacq., *A. marchalliana* Spreng. Species composing the boreonemoral (12.8 %) group were predominantly distributed in the zone of taiga and deciduous forests. The floristic core of this group included representatives of woody-shrub flora of pine forests: *Sorbus aucuparia* L., *Padus avium* Mill., *Populus tremula* L., *Ribes nigrum* L., *Frangula alnus* Mill. The herbaceous plants in this group was represented by *Lathyrus vernus* (L.) Bernh., *Scrophularia nodosa* L., *Impatiens noli-tangere* L., and some types of horsetails *Equisetum hyemale* L., *E. sylvaticum* L. Further, in descending order of the number of species in the latitudinal groups included in the floristic core of the studied pine forests, the groups were arranged in the following order:

- boreonemoral forest-steppe group (9.2 %), which included species of the family *Primulaceae*: *Lysimachia nummularia* L., *L. vulgaris* L., *Naumburgia thyrsiflora* (L.) Reichb. and *Humulus lupulus* L., *Verbascum thapsus* L., *Rubus saxatilis* L. and others;

- the nemoral forest-steppe and steppe (6.1 %) group combines plant species with their habitats both in the forest and steppe zones. Among them: *Allium rotundum* L., *Eupatorium cannabinum* L., *Inula helenium* L., *Senecio erucifolius* L., *Origanum vulgare* L., *Verbascum lychnitis* L., *Filipendula vulgaris* Moench, *Otites borystenica* (Grun.) Klok.;

- nemoral (5.3 %) group was represented in the floristic core largely by woody plants: species of the genus *Ulmus* (*U. glabra* Huds., *U. laevis* Pall., *U. mino*r

Mill.), *Tilia cordata* Mill., *Corylus avellana* L., *Quercus robur* L. *Euonymus verrucosa* Scop. and others;

- steppe (4.7 %) group included species such as: *Elytrigia intermedia* (Host) Nevski, *Chondrilla graminea* Bieb., *Salvia tesquicola* Klokov & Pobed., *Astragalus varius* S. G. Gmel., *Dianthus andrzejowskianus* (Zapal.) Kulcz., *D. campestris* Bieb. and others;

- the nemoral forest-steppe group (4.2 %) was represented in the floristic core of pine forests by such species as: *Carlina biebersteinii* Bernh. ex Hornem., *Pyrethrum corymbosum* (L.) Scop., *Vincetoxicum hirundinaria* Medik, *Aristolochia clematitis* L. and others;

- the forest-steppe group (3.4 %) was one of the small ones in the floristic core and included: *Tragopogon major* Jacq., *Leonurus quinquelobatus* Gilib., *Chamaecytisus ruthenicus* (Fisch. ex Wolosz.) Klask., *Prunus spinosa* L., *Geranium sanguineum* L. and others;

- boreal (2.5 %) group had the smallest share in the floristic core, but it included *Pinus sylvestris*, the edificator of the studied forests; other species in the group were: *Galium trifidum* L., *Spirodela polyrhiza* (L.) Schleid., *Lemna minor* L. and others.

It is interesting that of all groups, the largest number of species in the floristic core was retained by the nemoral forest-steppe and steppe group, which in the latitudinal spectrum of the flora of the studied pine forests occupied the last positions. Thus, 61.1 % of species from this group were included in the flora of the Usmansky pine forest. The largest number of species of this group was recorded in the core in the flora of Krasnosamarsky pine forest – 81.5 %.

More species ofthe forest-steppe and steppe and steppe groups were present in the core from the flora of the Usmansky and Khrenovskoy pine forests located in the forest-steppe zone than in the flora of the Buzuluksky and Krasnosamarsky pine forests located in the steppe zone. The opposite situation with the boreonemoral forest-steppe, nemoral forest-steppe, boreonemoral, nemoral and boreal groups, where a smaller proportion of species of the flora of Usmansky and Khrenovskoy pine forests entered the core than in the flora of Buzuluksky and Krasnosamarsky pine forests.

This is primarily due to the floristic structure of the Krasnosamarsky pine forest, which is located in the steppe zone, initially containing few forest species compared to the rest of the studied pine forests floras. On the other hand, in the floristic complex of the Usmansky pine forest, which is closest to the boreal flora among the studied ones, the number of forest-steppe, and steppe species is low. This, in turn, limits the presence of species of the respective groups in the core of the unified flora of pine forests.

Particularly important is the share of species groups containing representatives of forest floras and causing the greatest interest with respect to the relictness of the floras of the studied pine forests. These groups comprised from 37.6 % in the Usmansky, 32.6 % in the Khrenovsky, 34.6 % in the Buzuluksky, to 26.2 % in the Krasnosamarsky pine forests. Only 29.8 % of species from these groups participate in the floristic core.

Another important indicator of the value of flora is the presence of rare and endangered species, which are protected and/or listed in the Red Books of the regions. Territorially, the pine forests are located in different regions, and the Usmansky and Buzuluksky pine forests are located within two regions. Based on the information from the regional Red Data

Books (Shcherbakov 2014, Senator and Saksonov 2017, Agafonov 2018, Belov 2019), it is worth considering that species may have different protection status. In addition, being protected in the territory of one region, in another, these species may not have this status and be well distributed.

Almost half of the protected species of the Lipetsk Region were found in Usmansky pine forest (Table 4). For the Voronezh Region, the same pine forest is a refuge for one third of protected species of the region. About 20 % of protected species of the Voronezh Region occurred in the flora of Khrenovskoy pine forest.

Table 4. Number of species in the regional Red Data Books and their proportion in the flora of the studied pine forests.

Regions	Number of species in the Red Book of the region	Proportion of rare species in the flora of pine forests from those included in the Red Book of the region, %	
		Usmansky pine forest	Khrenovskoy pine forest
Voronezh	237	32.9	19.8
Lipetsk	175	45.7	-
		Buzuluksky pine forests	Krasnosamarsky pine forests
Samara	243	22.2	17.3
Orenburg	173	25.4	-

Approximately the same proportion of protected plants for the Samara and Orenburg regions is found in Buzuluksky pine forest.

In the flora of the Krasnosamarsky pine forest the share of protected species is not high and amounts to 17.3 % of all rare species included in the Red Book of the Samara region.

The proportion of protected species of all species accounted for in the flora of pine forests does not reach 10%. In the flora of the Usmansky pine forest, about 9% of species are protected in the Voronezh and Lipetsk regions. In the flora of Khrenovskoy pine forest, only 6.5 % of plant species included in the Red Book of the Voronezh region. The same percentage of protected species is noted in the flora of the Buzuluksky pine forest for the Orenburg region. The percentage of protected species in the flora of Buzuluksky pine forest for the Samara region is 8 %, and in the flora of Krasnosamarsky pine forest – 7 % of this region.

A compilation of a spectrum of latitudinal groups of protected species of flora of pine forests and floristic core was done (Table 5).

A high percentage of the species belonging to the forest group were protected.

The largest percentage of species from these groups falls on the flora of the Buzuluksky pine forest and totals 65.9 % for the Orenburg region and 61.1 % for the Samara region of all protected species accounted for in the flora of this pine forest.

In the flora of the Usmansky pine forest, protected species of the forest groups accounted for 60.3 % for the Voronezh region and 53.8 % for the Lipetsk region. The flora of Khrenovskoy pine forest contained 55.3 % of species of the forest groups for the Voronezh region among protected ones. Only 40.5% of species of the forest groups with a protection status in the Samara region entered the flora of Krasnosamarsky pine forest.

Of the protected species included in the floristic core, more than half (57.6 %)

Table 5. Spectrum of latitudinal groups of protected species of pine forests and core floras.

Latitudinal group	Number of species of flora of pine forests in the regions						Number of species in the floristic core of pine forests
	Lipetsk	Voronezh		Orenburg	Samara		
	1	1	2	3	3	4	
Boreal	24	27	15	7	16	4	5
Boreonemoral	7	10	8	9	9	7	7
Boreonemoral forest-steppe	5	4	2	6	4	2	5
Nemoral	7	6	1	7	4	4	2
Nemoral forest-steppe	6	4	1	2	2	1	2
Nemoral forest-steppe and steppe	3	2	1	1	2	2	2
Forest-steppe	8	6	6	1	1		1
Forest-steppe and steppe	8	5	6	5	6	6	6
Steppe	4	3	3		4	10	1
Plurizonal	8	11	4	6	6	6	2
Species in total	80	78	47	44	54	42	33

Note: 1 – Usmansky, 2 – Khrenovskoy, 3 – Buzuluksky, 4 – Krasnosamarsky pine forests.

belonged to the forest groups. From the boreal group here are marked: *Pyrola rotundifolia* L., *Adenophora liliifolia* (L.) A. DC., *Menyanthes trifoliata* L., *Juniperus communis* L., *Dryopteris carthusiana* (Vill.) H.P. Fuchs. Among the protected species from the boreonemoral group: *Carex bohemica* Schreb., *Listera ovata* (L.) R. Br., *Platanthera bifolia* (L.) Rich., *Paris quadrifolia* L., *Veratrum lobelianum* Bernh., *Dryopteris filix-mas* (L.) Schott, *Matteuccia struthiopteris* (L.) Tod. The composition of the floral core of the boreonemoral forest-steppe group includes such protected species as *Orchis militaris* L., *Iris pseudacorus* L., *Naumburgia thyrsiflora*, *Pulsatilla patens* (L.) Mill., *Thelypteris palustris* Schott. From the nemoral group in the floristic core, species with a protected status in the Orenburg region are *Euonymus verrucosa* and *Viola mirabilis* L.

Conclusions

The flora of the forests of the steppe and forest-steppe zones fully reflects the natural and climatic features of these areas, which is clearly visible in the spectra of the latitudinal groups. Nevertheless, one third of the floristic core is represented by species of forest groups. This is decisive in the character of the studied flora. The data obtained may be a confirmation of the concept on the relict nature of flora in insular pine forests due to the high representation of forest species in the core.

The obtained spectrum of latitudinal groups of protected species in the studied floras of pine forests and those included in the floristic core was also characterized by a high percentage of forest species determining the pine nature of the core.

In addition, the data obtained indicate

that for many steppe and forest-steppe regions, the pine forests may be the only habitats primarily for species from forest groups. For example, representatives of boreal flora: *Diphasiastrum complanatum* (L.) Holub., *Lycopodium annotinum* L., *L. clavatum* L., *Oxycoccus palustris* Pers., *Vaccinium myrtillus* L,. *V. vitis-idaea* L., *Chimaphila umbellata* (L.) W. Barton, *Orthilia secunda* (L.) House., *Pyrola chlorantha* Sw., *P. rotundifolia*, *Drosera rotundifolia*, *Hammarbia paludosa* (L.) O. Kuntze, *Neottianthe cucullata*, *Calla palustris*, *Maianthemum bifolium* (L.) F. W. Schmidt; boreonemoral *Botrychium virginianum* (L.) Sw. var. *europaeum* (Angstr.) Clausen; nemoral forest-steppe *Liparis loeselii* (L.) Rich.; nemoral *Salvia glutinosa* L. Examples of finding habitats on the territory of pine forests can also be species from other latitudinal groups: plurizonal *Hottonia palustris* L., steppe *Centaurea pineticola* Iljin.

Acknowledgments

The article was prepared within the framework of the topic of the state task of the Steppe Institute of the Ural Branch of the Russian Academy of Sciences for 2021–2025. Problems of steppe nature management in the context of modern challenges: optimization of the interaction of natural and socio-economic systems. No. AAAAA21-121011190016-1.

References

Agafonov V.A. 2006. Steppe, calcophilic, psammophilic and halophilic ecological and floristic complexes of the Middle Don basin: their origin and protection. Voronezh State University. 250 p. (in Russian)

Agafonov V.A. (Ed.) 2018. Vascular plants. Red Data Book of the Voronezh region: in two volumes, vol. 1: Plants. Lichens. Fungi. Voronezh, Center of Spiritual revival of the Chernozem Territory: 24–262 (in Russian).

Belov V.S. (Ed.) 2019. Plants. Red Data Book of the Orenburg region. Rare and endangered species of animals, plants and fungi. Voronezh, MIR LLC: 225–409 (in Russian).

Godnev E.D., Zaytsev B.D., Miron K.F., Nesterov V.G., Chardymov N.P. 1949. Buzuluksky pine forest. General outline and forest cultures. Goslesbumizdat. Vol. I: 5–13 (in Russian).

Chibilev A.A. 2008. Natural conditions of the territory of Buzuluksky bor. Buzuluksky bor: ecological and economic justification of the organization of the National Park. Vol. 1, Ural Branch of the Russian Academy of Sciences: 7–17 (in Russian).

Crichfield W.B., Little Jr.E.L. 1966. Geographic distribution of the pines of the world (Washington, DC: U.S. Department of Agriculture, Forest Service, Misc. Publ.) no 991. 64 p.

Darkshevich Ya.N. 1953. Buzuluksky forest. Chkalov publishing house. 88 p. (in Russian).

Gerasimov I.P., Markov K.K. 1939. Ice age on the territory of the USSR: Physical and geographical conditions of the ice age. Publishing House of the Academy of Sciences of the USSR. 462 p. (in Russian).

Gorchakovsky P.L. 1987. Forest oases of the Kazakh melkosopochnik. Nauka. 158 p. (in Russian).

Gordyagin A.Ya. 1897. About the Kokchetav forests. Notes of the West Siberian Branch of the Russian Geographical Society, vol. 22: 1–18 (in Russian).

Gribanov L.N. 1960. Steppe forests of the Altai Territory and Kazakhstan. Goslesbumizdat. 156 p. (in Russian).

Grigorievskaya A.Ya., Starodubtseva E.A., Khlyzova N.Yu., Agafonov V.A. 2004. Alien flora of Voronezh Region: historical, biogeographic, ecological aspects. Voronezh: Voronezh State University Press. 320 p. (in Russian).

Gvozdetsky N.A. 1968. Physical and geo-

graphical zoning of the USSR: textbook. MSU. 577 p. (in Russian).

Kazmin S.P. 2017. Genesis ancient stream of the Ob-Irtysh interfluves. Interexpo GEO-Siberia 3(2): 224–229 (in Russian).

Kin N.O. 2009. Flora of Buzuluksky pine forest (vascular plants). Proceedings of the Buzuluksky Bor scientific station-branch of the Steppe Institute UB RAS, vol. 2. Yekaterinburg, UB RAS. 283 p. (in Russian).

Kin N.O., Senator S.A. 2020. Ecological-coenotic structure of the pine forest flora at the southern margin of the geographical range of *Pinus sylvestris* L. IOP Conference Series: Earth and Environmental Science: 4th Conference on Actual problems of specially protected natural areas: IOP Publishing Ltd. Conf. Series: Earth and Environmental Science 607, 012006. DOI: 10.1088/1755-1315/607/1/012006

Kin N.O., Starodubtseva E.A. 2012. Annotated list of vascular plants of Khrenovskoy pine forest. Proceedings of the Voronezh Nature Reserve 26: 64–144 (in Russian).

Kliment'ev A.I. 2010. Buzuluksky forest: soils, landscapes and factors of the geographical environment. Ural Branch of the Russian Academy of Sciences. 397 p. (in Russian).

Korchikov E.S., Prokhorova N.V., Plaksina T.I., Matveev N.M., Makarova Yu.V., Kozlov A.N. 2009. Floral diversity of the most valuable Krasnosamarsky forest in the Samara region: I. Vascular plants. The Samara Region: Issues of Regional and Global Ecology 18(3): 187–191 (in Russian).

Krasheninnikov I.M. 1939. The main ways of vegetation development of the Southern Urals in connection with the paleogeography of Northern Eurasia in the Pleistocene and Holocene. Soviet botany 6–7: 67–99 (in Russian).

Kremenetsky K.V., Betger T., Klimanov V.A., Tarasov A.G., Junge F. 1998. History of flora and climate of Buzuluk's coniferous forest in holocene and late glaciation periods and their paleogeographical value. Izvestiya Rossiiskoi Akademii Nauk. Seriya Geograficheskaya, No 4: 60–74 (in Russian).

Kulikov P.L. 2005. Synopsis of the flora of the Chelyabinsk region (vascular plants). Geotour. 537 p. (in Russian).

Markov K.K., Velichko A.A. 1967. Quaternary period. Nedra. 440 p. (in Russian).

Matveev S.M., Matveeva S.V., Shurygin Yu.N. 2012. Recurrence of severe droughts and long-term dynamics of radial increment of the Scots pine in the Usman and Khrenovoe forests in the Voronezh region. Journal of Siberian federal university. Biology 5 (1): 27–42 (in Russian).

Milkov F.N. 1977. Natural zones of the USSR. 293 p. (in Russian).

Pallas P.S. 1809. Travel to different provinces of the Russian Empire. Part 1. 657 p. (in Russian).

Pavlov N.V. 1948. Botanical Geography of the USSR. Academy of Sciences Kaz. USSR. 704 p. (in Russian).

Saksonov S.V, Senator S.A. 2012. A guide to the Samara flora (1851–2011). Flora of the Volga basin, vol. 1. Togliatti, Kassandra. 512 p. (in Russian).

Senator S.A., Saksonov S.V. (Eds) 2017. Red Data Book of the Samara region, vol. 1. Rare species of plants and fungi. Samara State Regional Academy (Nayanova) Publishing House: 19–304 (in Russian).

Seregin A.P. 2015. Local flora at MSU student zonal field camps: 3. Khrenovskoy pine forest (Voronezh region); 4 and 5. Additions to floras of tree entanglements (the Tula region) and Polibino (the Lipetsk region). Phytodiversity of the Eastern Europe 9(2): 42–73 (in Russian).

Shcherbakov A.V. (Ed.) 2014. Vascular plants. Red Data Book of the Lipetsk region, in 2 volumes, vol. 1: Plants, Fungi, Lichens. Lipetsk, Veda Socium LLC: 118–495 (in Russian).

Starodubtseva E.A. 1999. Flora of the Voronezh Nature Reserve. Vascular plants, mosses, lichens, fungi. Flora and Fauna of Nature Reserves 78: 5–96 (in Russian).