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APPLIED PROBLEMS OF ARID LAND DEVELOPMENT

Preserved Sections of Steppes as the Basis for the Future Ecological Framework of Belgorod Oblast

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Abstract—Belgorod oblast is a region of ancient economic development with the highest level of agricultural land use in Russia and, accordingly, the highest level of anthropogenic transformation of zonal vegetation and soils (chernozems). Despite all of the efforts of recent years to improve the conservation of territorial nature in the region, all categories of specially protected territories make up only 1.8%, which is one of the lowest rates in the Russian Federation. Steppe plots occupy less than 10% of the area of all protected areas, i.e., 0.2% of the region's area, which cannot serve as the basis for the conservation of steppe biodiversity and the formation of the ecological framework of the region, where the zonal type of vegetation is steppes. The article provides a historical analysis of the transformation of the region's steppes, the results of an inventory with remote sensing methods of the preserved sections of the steppes, assessment of the potential of their flora for the development of restoration succession, and the effectiveness for preservation of the steppe biodiversity of the regional network of specially protected areas and the formation of an ecological framework. It is shown that more than 700 identified sites with preserved steppe vegetation (about 47000 ha) are small-contoured and fragmented and are located on the nonarable and strongly eroded slopes of draws and narrows. Without special events, they are not able to become the basis of the ecological framework. Approaches and methods of stimulating the restoration of the steppes on post-agrogenic and technogenic lands of the region are proposed.

Keywords: steppe, forest–steppe, meadow, real and cretaceous steppes, Belgorod oblast, protected areas, ecological framework, chernozems, restoration succession, succession system, Belogorye reserve, Lebedinsky mining and processing plant

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INTRODUCTION

In Belgorod oblast, specially protected areas (SPNAs) of all categories and levels of management have a total area of 47600 ha, which is only 1.8% of the territory of the region. This is one of the lowest rates among the constituent entities of the Russian Federation. The formation of a regional network here is due to areas of secondary forests, steppe tracts, and draws that are occupied by degraded vegetation and unsuitable for agricultural activities. Steppes are practically not represented (Smelyanskii and Titova, 2018; Smelyansky and Tishkov, 2012). Protected forest areas are concentrated mainly near settlements and fulfill recreational functions; in general, the share of forests in protected areas reaches 80–85%. In 2012, the certification of protected areas was carried out in the region. In that year, 351 regional and 5 federal sites, the Belogorye Reserve, were included in the inventory of protected areas. The average area of the protected areas of the region does not exceed 100–150 ha, which virtually eliminates the observance of the conservation regime on them and results in negative impact from neighboring territories used in the economy. Due to the high level of agricultural development in the region, the steppe vegetation has been preserved mainly along the draws, occupying quite large areas (up to 100 ha). The main part of these protected areas is represented by calcite-like flora: Melovaya Gora, Varvarovka (Alekseevsky district), Svyachenaya Gora, Snizhennye Alpy (Volokonovsky district), and Snizhennye Alpy tract (Konoplyanka village, Valuysky district). There are sections of grass-meadow and forb-feather grass steppes. Among them are protected areas such as Khvoshchevatoe (Krasnensky district), a section of meadow steppe (Rovensky district), and the

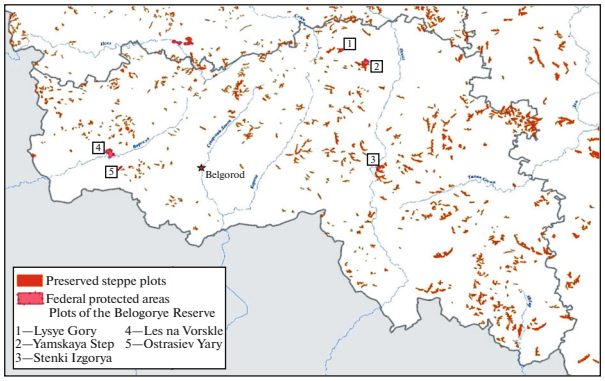

Fig. 1. Preserved sections of the steppe vegetation of Belgorod oblast.

Log Krutenkiy and Gniloe draws (Veidelevsky district). An example of complex reserves in the region are the Borki and Gorodishche tracts with large colonies of marmot–baibak and unique cretaceous outcrops. Of great interest are botanical sanctuaries, the Khvoshchevatoe and Gniloe tracts, with a calcite-like flora, e.g., Bekaryukovsky pine forest, sections of grass–meadow and forb–feather grass steppes.

At present, the situation with the organization of the regional network of protected areas has changed somewhat. After the Decree of the Government of the Belgorod Region dated August 15, 2016 no. 299-pp, a network of 290 protected areas is functioning in the region, including 76 "natural parks", which are green (mainly forest plantations) plantings of varying degrees of conservation and of different origin, 114 regional nature reserves, among which forest sites, draws and ponds prevail, 107 natural monuments (springs, old trees, parks), two arboretums and one botanical garden, as well as the Belogorye State Nature Reserve with the sections Les na Vorskle, Yamskaya Step, Lysye Gory and Stenky Izgorya with a total area of only 2500 ha. Fully steppe plots among all categories of protected areas are not numerous and make up less than 10% of the area of all protected areas, i.e., 0.2% of the region's area, which cannot serve as the basis for the formation of the ecological framework of such a steppe region as Belgorod oblast, and its regional network of protected areas. The real basis of the future ecological framework is areas of steppe vegetation that preserves the gene pool of the steppe biodiversity of the region as a potential for its restoration.

The purpose of this article is to determine the potential of the preserved sections of the steppe vegetation of Belgorod oblast and their flora, to identify their abilities for the formation of its ecological skeleton and regional network of protected areas, and to assess the prospects of full-fledged secondary succession on agro-industrial and technogenic lands.

MATERIALS AND METHODS

The materials for this article have been collected over the years (since 2014) from the retrospective study of historical documents and maps (e.g., digitization of the "General Geometrical Plan of the Kursk Governorate in 1785"), analysis of modern satellite imagery to identify preserved sections of the steppes and field verification of the results of remote sensing (ERS) during expeditions, and analysis of the floristic database materials maintained in the biogeography laboratory of the Institute of Geography of the Russian Academy of Sciences. According to the results of an inventory of the steppes of the European part of Russia (Rogova and Skvortsova, 2016) and studies of the Institute of Geography, together with colleagues from the Central Black Earth Reserve and Kursk University (Tishkov et al., 2012; Zolotukhin et al., 2014), 702 sites were identified with preserved steppe vegetation on an area of about 47000 ha, which is less than 1.7% of the entire region. That is, the area occupied by the steppe communities decreased by more than 35 times from its likely initial state at the beginning of the mass development of the region to the end of the 16th century (Fig. 1). The identified areas are small and fragmented and are located on nonarable and strongly eroded slopes of draws and narrows. Most of them have an area of less than 100 ha. The largest of them, with an area of more than 850 ha, is located on the border of the Valuysky and Krasnogvardeisky districts and represents the vast cretaceous slopes of the Polatovka River valley.

In addition, a systematic study of the flora of steppe areas identified by remote sensing was begun in order to determine the potential for the stimulation of self-restoration processes (the development of secondary succession in degraded areas) and the use of local genetic material for the ecological restoration of post-agrogenic and technogenic lands. In parallel, on areas of the Belogorye Reserve adjacent to the technogenic lands of the Lebedinsky mining and processing plant (Yamskaya Step, Lysye Gory), an unmanned aerial vehicle and ground-based observations are used to assess changes in the structure of the vegetation cover, including the processes of the settlement of woody–shrubby vegetation in the steppe. These materials will be retrospectively analyzed to establish trends in the dynamics of the reserve's vegetation in order to identify actually reservatogenic and climatogenic successions.

RESULTS AND DISCUSSION

Anthropogenic Transformation of the Steppes of Belgorod Oblast

In retrospect, it is extremely difficult to trace the stages of the anthropogenic transformation of the steppe vegetation of the region, because, for more than 1000 years, it was administratively included in various

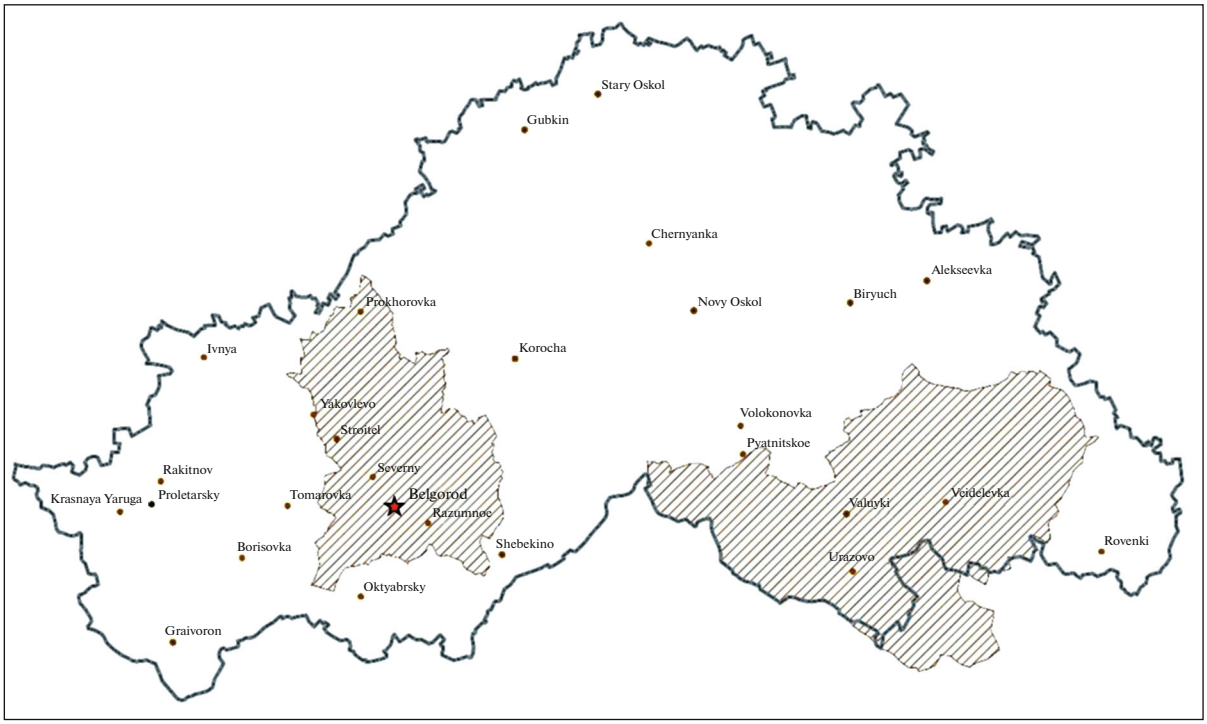

Fig. 2. Belgorod and Valuysky uyezds of Belgorod province according to the "General Geometrical Plan of 1785."

state entities, divided between them and united, and included and excluded from Russia. In its modern borders, Belgorod oblast was formed in 1954.

Throughout the 1000-year history of the region, its landscapes underwent significant changes: (1) there was intensive plowing of chernozemic lands (they initially occupied about 75% of the territory; Chendev et al., 2017), (2) the native broad-leaved forests were reduced (previously gray forest soils occupied up to 15%), (3) steppe fires periodically violated the natural course of soil formation (Chendev and Gennadiev, 1993), (4) the density of the river network of the region decreased, its water content increased, the and the floodplain complexes degraded (from the end of the 18th century the total length of the region's rivers decreased more than 20% due to erosion and drainage changes 10–20 km of rivers are lost each year).

We conducted a retrospective analysis of the dynamics of the lands of the region based on the digitization of the "General geometric plans of the Kursk and Voronezh governorates of 1785–1789" within the boundaries of Belgorod and Valuysky uyezds (Fig. 2). In the current administrative division of the region, the borders of the Valuysk uyezd include most of the Valuysky district, all of Veidelevsky, the southern part of Volokonovsky and Krasnogvardeisky, the northwestern part of Rovenky, and the extreme southwestern part of Alekseevsky. The Belgorod Uyezd includes part of the Belgorod region together with the city of Belgorod, the eastern part of Yakovlevsky, southern Prokhorovsky, western Korochansky, and northwestern Shchebekinsky. In accordance with the scheme of botano-geographic zoning (Isachenko and Lavrenko, 1980), the territory of the Belgorod region lies within the Eurasian steppe region, at the junction of the East European forest–steppe and Black Sea (Pontic) steppe provinces and belongs to the East European forest–steppe province, for which the zonal vegetation types are broad-leaved forests and northern meadow (feather–grass–forb) steppes. The zonal type is upland meadow and real (herb—fescue–feather grass) steppes (including their calciphytic and psammophytic variants). The degree of their preservation can be estimated from Table 1 and Figs. 3 and 4.

Thus, by the end of the 18th century, grass ecosystems accounted for 20.9% of the territory of the *Belgorod Uyezd*, and forests constituted 24.4%. Almost all other lands were arable land. Residential and commercial development accounted for about 1–2% of the area. In Valuysky district, the steppes made up ~38%, forests were 8%, residential land accounted for 10%, and the rest was arable land. Floodplain wet areas and artificial reservoirs were no more than 2%. That is, one can see that the area of arable land in the 18th century exceeded 40% and that agricultural land as a whole occupied the majority of the uplands.

Since the floodplain meadows were used for haying and grazing and there is sparing use of the steppes in both of these types of agricultural land, it can be assumed that almost all of their area in 1785 was occupied by zonal vegetation and its edaphic options. In more than 230 years, their area decreased by 23–24 times. The loss

Table 1. Areas occupied by forest and grass vegetation within the borders of Belgorod and Valuysky uyezds of the former Belgorod province of the 18th century in comparison with the areas of modern preserved steppes (red color in Figs. 3–4)

Region	State of the land in the 18th century			Preserved sections of the steppe, ha (21st century)
	total area of the uyezd, ha	including forests, ha	including grassland (steppe and meadow-steppe hayfields and pastures), ha	
Belgorod Uyezd	244619	59680	51104	2229
Valuysky Uyezd	394610	31723	149795	6279

rate was 624 ha per year for Valuysk uyezd and 213 ha per year for Belgorod uyezd.

Potential of Flora of Belgorod Oblast for Steppe Restoration

The initial vegetation cover of the considered territory was mainly steppe. Now, chernozems occupy ~70% of the soil cover, i.e., agrocenoses were created on the site of meadow grass–forbs and true forb–fescue–feather grass steppes. According to local experts, the flora of the region includes about 1300 species, of which more than 310 species are steppe, including 93 characteristics of the cretaceous steppes. In the meadows, including steppe, 232 species are noted.

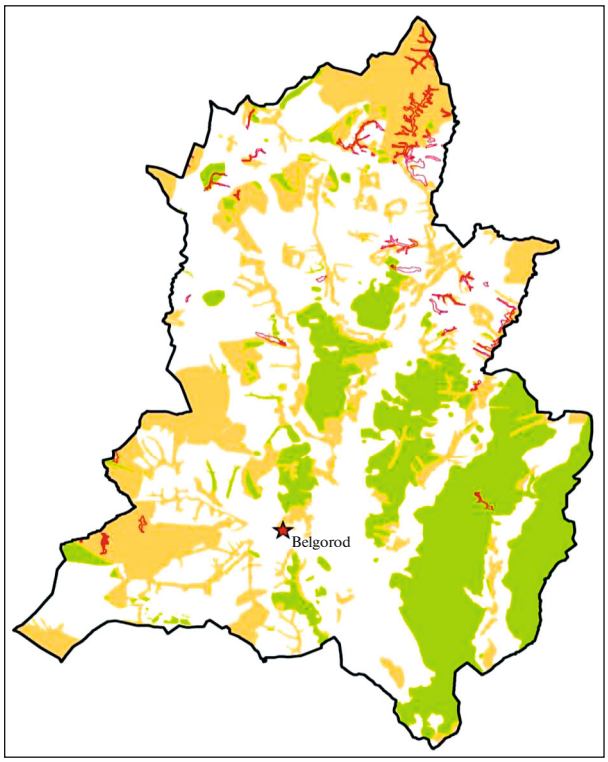

Fig. 3. Distribution of forests (green) and steppe hayfields and pastures (yellow) on the territory of Belgorod uyezd in the 18th century as compared with the areas of the modern preserved steppes (red color).

The rest of the flora is represented by forest, shrub and marginal, wetland and synanthropic species and has 192 species. According to our data obtained from materials in the database of adventive plant species maintained at the Institute of Geography of the Russian Academy of Sciences (RF Inventor's Certificate ..., 2011), there are about 220 adventive species in the flora of Belgorod oblast. Since there were 1230 species of vascular plants from 108 families in the flora compendium at the end of the 20th century, of which only 1168 were confirmed to grow (Elenevskii et al., 2004), it can be recognized that the region is an arena of active development of invasive species, especially from Asteraceae, Brassicaceae, and Poaceae (Sukhorukov and Kushinina, 2012).

The nature reserves of the steppe flora occupy only 2500 ha in the region, and the fragments of preserved sections of meadow, real, and cretaceous steppes that have been identified and have acquired the status of regional protected areas have an area of only 10–50 ha (with the exception of the steppes near the village of Kovalevo in the Alekseevsky district, which occupy 348 ha); protected areas cannot be considered a reserve for large-scale restoration of the steppe vegetation of the region. Another issue is the remaining sections of the steppes identified during the inventory process with ERS, including cretaceous sections (about 47000 ha). Although the flora of these areas is not depleted due to their inconvenience, they are quite suitable for the role of seed suppliers and for the stimulation of restoration succession (Fig. 5).

How correct is this conclusion? Up to 100–200 species of steppe and meadow plants are represented In each of the identified 702 plots, and, together, they represent almost the entire pool of steppe flora, including protected species from the federal and regional Red Books, up to 14 species per registration area (*Krasnaya kniga* ..., 2005, 2008)! For comparison, the diversity of flora in the steppe federal protected areas of the region ranges from 571 (Lysye Gory) to 640–700 species (Yamskaya Step, Stenky Izgorya). The first steps have been taken in the reintroduction of rare and endemic species of flora of Belgorod oblast (thin-leaved peony, pygmy iris, *Hyssopus cretaceus*, etc.) (Ermakova and Gusev, 2017).

As of October 1, 2004, 166 species of vascular plants (the main list) were included in the Red Data

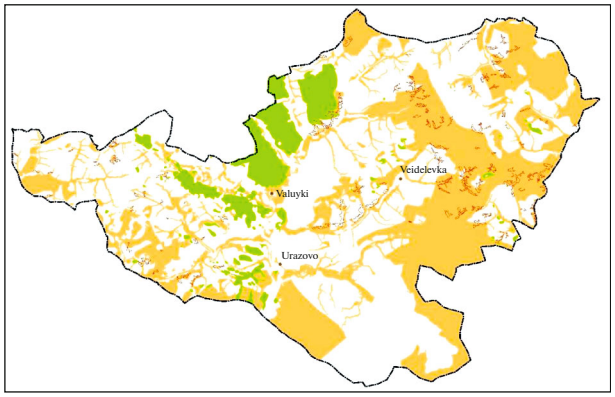

Fig. 4. Distribution of forests (green) and steppe hayfields and pastures (yellow) on the territory of Valuysk uyezd in the 18th century as compared with the areas of the modern preserved steppes (red color).

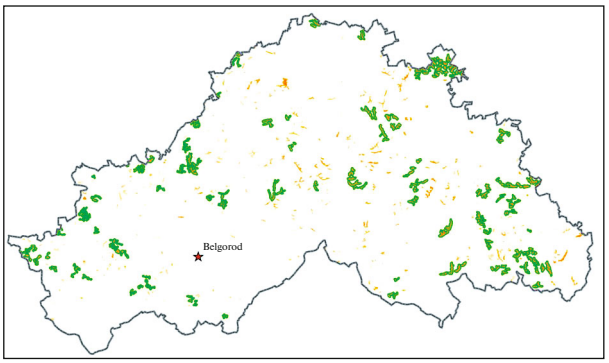

Fig. 5. Groups of preserved steppe sites located at a distance of no more than 1000 m from each other and belonging to systems of different draws ("steppe" basis of the future ecological framework of Belgorod oblast).

Book of Belgorod oblast (2005), of which 98 are steppe (including, in fact, steppe, meadow-steppe, calcephilic-steppe, psammophilic-steppe halophilic-steppe). The main list of the new edition of the Red Book recommended 264 species of vascular plants (Gusev et al., 2017). Of this list, 162 species belong to the steppe: proper steppe—55, meadow steppe—24, calcephilic-steppe—52, psammophilic-steppe—15 species, halophilic-steppe—16 species. On the territory of the Belogorye Reserve there are 77 species of steppe plants recommended in the new edition of the regional Red Book, in the following areas: Yamskaya Step (566 ha, since 1935)—51 species, Lysye Gory (170 ha, since 1993)—50, Stenki Izgorya (267 ha, since 1995)—48 species, Ostrasievy Yary (90 ha, since 1995)—16 species, Les na Vorskle (1038 ha, since 1925)—mainly forest, no protected steppe species in the flora.

Twenty-nine species of steppe plants of Belgorod oblast are included in the Red Data Book of the Russian Federation (2008), of which 12 are noted in the areas of the Belogorye Reserve: *Pinus sylvestris* var. *cretacea* (Stenki Izgorya), *Bulbocodium versicolor* (Yamskaya Step, Lysye Gory), *Fritillaria ruthenica* (Yamskaya Step, Lysye Gory, Stenki Izgorya), *Iris aphylla* (Yamskaya Step, Lysye Gory, Stenki Izgorya, Ostrasievy Yary) *Stipa dasyphylla* (Yamskaya Step), *Stipa pennata* (Yamskaya Step, Lysye Gory, Stenki Izgorya), *Stipa pulcherrima* (Yamskaya Step, Lysye Gory, Stenki Izgorya), *Stipa zalesskii s.* l. (Yamskaya Step), *Pulsatilla pratensis s.* l. (Ostrasievy Yary), *Hedysarum grandiflorum* (Stenki Izgorya), *Daphne altaica s.* l. (Stenki Izgorya), and *Androsace koso-poljanskii* (Yamskaya Step, Lysye Gory). Another ten species are found in the Rovensky region within the plots of the Rovno Nature Park: *Bellevalia sarmatica*, *Iris pumila*, *Genista tanaitica*, *Hedysarum ucrainicum*, *Erucastrum cretaceum*, *Matthiola fragrans*, *Artemisia hololeuca*, *A. salsoloides*, *Scrophularia cretusa creaceusus*, and *Hyphus creusaceus*. The protection for the Rovensky nature park is unsatisfactory. As extremely negative actions, we note the planting of forest crops (the Green Capital regional program) in 2010 on the Lysaya Gora site (the right bank of the Aydar River) along steppe slopes with many rare plant species, including *Stipa lessingiana*, *S. pennata*, *Artemisia hololeuca*, *Matthiola fragrans*, and *Scrophularia cretacea*. It is necessary to resolve the issue of the transfer of some of the plots (Aidarsky, Sarma, etc.) of the Rovensky Nature park to the Belogorye Nature Reserve.

As noted above, regional protected areas cannot be considered places that preserve the regenerative potential of the flora (Tishkov et al., 2018a, 2008b). Since Belgorod oblast is a completely anthropogenically changed region with a high level of economic load, we note that landscapes in close proximity to the natural state are absent here, even in protected areas (Fig. 6). Some of them lost the ability to self-repair during their long agrarian development or as a result of destruction during mineral extraction, i.e., invariant properties providing the natural course of restoration succession. There is no confidence in the safety of the entire pool of species that form the full-fledged early, middle, and especially climax stages of recovery successions. In relation to the final (climax) stages of successions of the steppes (meadow, real, cretaceous, and petrophilic), there is "diaspora hunger"—a deficiency of seed for the formation of communities similar to natural ones. Most of the steppe areas preserved in the region are small-contour, fragmented, and confined mainly to the so-called "badlands" taken from agricultural production—steep eroded slopes, pastures, etc. They are usually removed from areas that require restoration of vegetation, which are abandoned quarries, dumps, and eroded slopes, i.e., rapid seed transfer for the development of the self-restoration process in these areas is excluded.

The soil stock of seeds in postagrogenic soils and on exposed lands of abandoned quarries for the

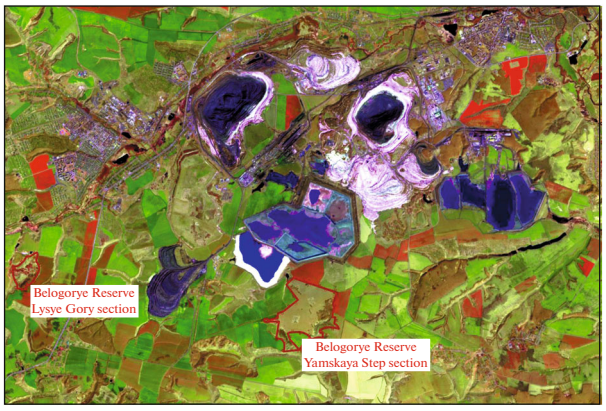

Fig. 6. Position of 2 sections of Belogorye Reserve in the agricultural and industrial landscape of Belgorod oblast. There are no steppe areas in the immediate environment.

extraction of sand, loam, and melting marl rocks consists exclusively of seeds from a weed complex, including adventive and invasive plant species. Each site has "reduced" flora. Moreover, the degree of transformation can be estimated via comparison of the quantitative composition of the flora in the steppe areas of Belogorye Reserve and the steppe areas identified during the inventory process. They are floristically 2–2.5 times poorer and lack key species for restoration. This does not allow, at the expense of the local pool of flora, the formation of full-fledged succession stages or, in the case of the primary substrate, pioneer groups that give rise to soil formation along the steppe trend.

Though unsuitable for plowing, many of the sites were threatened with extinction, especially the cretaceous steppes, due to direct planting (Titova et al., 2014). Historically, judging by the nature of the distribution of chernozem soils, the zonal ecosystems of the forest–steppe and steppe prevailed here; the border between them lies in the Alekseevsky, Valuysky, and Veydelevsky districts, and the Rovensky region was almost entirely considered steppe (Dohman, 1968). However, despite some zonal differences between the forest–steppe and the steppe due to strong agrogenic transformation, the region has, in our opinion, a phylocenogenetically uniform regional succession system, which, with an abundance of rows and series, has only a few terminal stages (at least four—oak forests, meadow and real steppes, and cretaceous steppes). They are formed through the corresponding rows and series of digressive–demutational changes in plant communities, due to the genesis of vegetation disturbances (agrogenic, pyrogenic, sedimentary, technogenic, etc.), as well as the nature of the original habitats determined by the soil cover (from leached and podzolized chernozems to typical carbonate cretaceous, etc.), humidification conditions (from dry to moderately wet), and underlying rocks (sands, cretaceous, loess-like loams and clays, crushed stony soils, etc.). It is methodologically important to imagine that these diverse stages that formed in the process of succession—from pioneer and long-term derivatives to subclimax and climax—is the repository of the main part of the floristic pool (elementary flora, specific flora). A regular reduction of restoration successions due to diaspora hunger is noted for zonal meadow-steppe vegetation.

With regard to the quarries, dumps, and eroded slopes in the region, the idea of the nature of the course of primary successions with respect to the substrate has not yet developed (Kornilov et al., 2015), and the potential of the local flora, with allowance for the geological, geochemical and hydrological conditions of anthropogenic lands, can be considered conditionally, without the confinement of plant species to new substrates.

By the potential of local flora for reductive succession, we mean the set of plant species of different succession status that can participate in the composition of the early, middle, and final (climax) stages of succession (Tishkov et al., 2018a). Apparently, the question of the location of random elements of the invasive part of the flora (ephemerophytes) in this case cannot be considered. However, species that have gone through all of the stages of adventitization and are included in the succession system of this old-developed area, in our opinion, may well be considered new elements that have received their regional succession status. An important quality of species composing the local steppe flora is coenophilism, i.e., the ability to form communities and to exist in their ensemble. In the specification of the potential of local flora, it can become a criterion for exclusion from consideration coenophobes—autochoric, anthropochoric, and, in fact, synanthropic. Some of them became widespread in the old, developed steppe regions due to the widespread formation of weed complexes that block restoration succession in fallows and nonarable land.

To assess the possibility of an exchange of sections of preserved steppe vegetation and their seed material, we analyzed the distances between individual fragments of preserved steppes belonging to a system of different draws (Fig. 5). Based on the assumption that there are no significant obstacles to this exchange within one draw under the presence of suitable conditions, 1 km was chosen as the critical distance. In the absence of accurate data and practically any work on the seed distribution of steppe plants, this figure was chosen as a certain theoretical justified distribution limit of the seed material of the plants presented here. As a result of the analysis, these steppe sections were grouped into clusters within which such an exchange is possible. The analysis allows us to conclude that most of the draws with sections of the steppes are located at a distance greater than 1 km from each other, and therefore, in most cases, cannot exchange genetic material with each other. That is, those species of plants that have a smaller radius of seed distribution

(less than 1000 m) can no longer go beyond the boundaries of a particular site. They can, however, serve as the "steppe foundation" of the future ecological framework if full-scale work on ecological restoration of the steppes is started in the region.

CONCLUSIONS

The prospects for the restoration of steppe vegetation in the formation of the ecological framework of Belgorod oblast are obvious. However, at present, there are no real opportunities for the self-restoration of steppe vegetation on agricultural lands that are being withdrawn from use or technologically disturbed lands (Fig. 6). Their future is connected exclusively with the processes of biological reclamation and ecological restoration, the stimulation of restoration successions, and the use of local flora for this. The 702 sites of preserved steppes that we identified should receive the conservation status of "seed reserves," which serve as places of seed generation and distribution of steppe plants. However, the likelihood that they will be able to compensate for "dysporic hunger" in large areas deprived of steppe vegetation is extremely small. The distances between potential seed reserves are large (tens of kilometers; Fig. 5); they have an extremely reduced composition of the steppe flora and are located on the slopes and even the lower part of the draws, which makes it difficult to use the main mechanisms of seed distribution for steppe plants (anemochoria and ballistochoria). The wind serves as the main agent for the distribution of seeds of steppe plants of the first, second, and even third tiers. Together, ballista and anemochora in the steppe phytocenoses account for about 70% (only about 30% in the first tier). Zoochoria, as our observations in the region show, cannot be considered among the leading factors in the natural distribution of seeds of steppe plants. Some myrmicochone plants spread over short distances.

In the case of Belgorod oblast, one should focus on the use of seed reserves of the steppe flora in the preserved sections of the steppes for the ecological restoration of disturbed lands. In the process of summer mowing and further hay threshing from 1 ha of seed reserve, one can get up to 1–2 centners of "hay-seed dust," in which seeds of dozens of species of steppe cereals and forbs are present. If we use the steppe restoration methods developed earlier (Tishkov and Danilov, 1998; Tishkov, 2000), then the available reserves of the flora of the region are sufficient only to obtain seeds for restoration of about 150000 ha—about 5% of the area (based on the fact that 1 ha of steppe gives a seed mixture for restoration of 5 ha), which is not enough for the formation of the "steppe" part of the ecological framework). This means that special measures are required to protect the vegetation and ensure the seed distribution of steppe plants. The identified areas of the preserved steppes of the region should receive the status of seed reserves, but special "seed nurseries of local flora" and protection measures are also needed to ensure the distribution of steppe species to land restoration.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest. The authors declare that they have no conflict of interest.

Statement on animal welfare. This article does not contain any studies involving animals performed by any of the authors.

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