Трансформация экосистем
Ecosystem Transformation

ISSN 2619-0931 Online
www.ecosysttrans.com

DOI 10.23859/estr-230809
EDN KZLRZS
UDC 581.93 (470.61-25)

Article

Woody flora of the Northern city cemetery of the Rostov-on-Don city, Russia

B.L. Kozlovsky*, P.A. Dmitriev, M.V. Kuropyatnikov, O.I. Fedorinova

Southern Federal University, Bolshaya Sadovaya St. 105/42, Rostov-on-Don, 344000 Russia

**blk@sfedu.ru*

Abstract. The woody flora of the Northern city cemetery of Rostov-on-Don comprises 18 native and 64 alien species of woody plants. The species of North American (36%) and European (22%) origin dominate, followed by East Asian and Chinese species (13%), as well as Eurasian species (11%). Taxa of other origin are represented by single species. In total, 21 alien species disperse spontaneously throughout the cemetery territory by means of seeds, mainly by anemo-, ornitho-, and anthropochory. The most abundant and frequently met alien species, which settled on the cemetery territory spontaneously, are *Acer negundo*, *Acer negundo*, *A. platanoides*, *Ailanthus altissima*, *Celtis occidentalis*, *Fraxinus pennsylvanica*, *Juglans regia*, *Malus domestica*, *Morus alba*, *Prunus armeniaca*, *P. cerasifera*, *P. mahaleb*, and *Ulmus pumila*. The reproduction of woody species in the cemetery is facilitated by the presence of specific crevice habitats. We suppose that over time the species composition of woody plants will become unified throughout the cemetery. Such species as *A. negundo*, *A. altissima*, *C. occidentalis*, *F. pennsylvania*, and *U. pumila* will probably dominate in emerging vegetation.

Keywords: woody plants, alien species, native species, invasive species, anemochory, ornithochory, anthropochory, spontaneous dispersal of plants, crevice habitats

Funding. The study was supported by the Ministry of Science and Higher Education of the Russian Federation (state assignment no. FENW-2023-0008).

ORCID:
B.L. Kozlovsky, https://orcid.org/0000-0001-9410-1854
P.A. Dmitriev, https://orcid.org/0000-0001-5740-5146

To cite this article: Kozlovsky, B.L. et al., 2025. Woody flora of the Northern city cemetery of the Rostov-on-Don city, Russia. *Ecosystem Transformation* **8** (1), 108–122. https://doi.org/10.23859/estr-230809

Received: 09.08.2023
Accepted: 21.09.2023
Published online: 21.02.2025

DOI 10.23859/estr-230809
EDN KZLRZS
УДК 581.93 (470.61-25)

Научная статья

Дендрофлора Северного городского кладбища города Ростов-на-Дону

Б.Л. Козловский*, П.А. Дмитриев, М.В. Куропятников, О.И. Федоринова

Южный федеральный университет, 344000, Россия, г. Ростов-на-Дону, ул. Большая Садовая, д. 105/42

**blk@sfedu.ru*

Аннотация. По результатам анализа дендрофлоры Северного городского кладбища Ростова-на-Дону выявлено, что на территории кладбища представлено 18 аборигенных и 64 чужеродных вида древесных растений. Среди них лидируют виды североамериканского (36%) и европейского (22%) происхождения, им уступают восточноазиатские и китайские (13%), а также евроазиатские виды (11%). Виды другого происхождения представлены единично. 21 чужеродный вид спонтанно расселяется по территории кладбища посредством семян, в основном при помощи анемо-, орнито- и антропохории. Среди спонтанно расселившихся на территории кладбища чужеродных видов по обилию и встречаемости лидируют *Acer negundo*, *A. platanoides*, *Ailanthus altissima*, *Celtis occidentalis*, *Fraxinus pennsylvanica*, *Juglans regia*, *Malus domestica*, *Morus alba*, *Prunus armeniaca*, *P. cerasifera*, *P. mahaleb* и *Ulmus pumila*. Воспроизводству на территории кладбища древесных видов способствует наличие специфических щелевых местообитаний. Можно ожидать, что со временем произойдет унификация видового состава древесных растений по всей территории кладбища. В составе формирующейся растительности, вероятно, будут лидировать такие виды, как *A. negundo*, *A. altissima*, *C. occidentalis*, *F. pennsylvanica* и *U. pumila.*

Ключевые слова: древесные растения, чужеродный вид, аборигенный вид, инвазионный вид, анемохория, орнитохория, антропохория, спонтанное расселение растений, щелевые местообитания

Финансирование. Исследование выполнено при финансовой поддержке Министерства науки и высшего образования РФ в рамках государственного задания в сфере научной деятельности № FENW-2023-0008.

ORCID:
Б.Л. Козловский, https://orcid.org/0000-0001-9410-1854
П.А. Дмитриев, https://orcid.org/0000-0001-5740-5146

Для цитирования: Козловский, Б.Л. и др., 2025. Дендрофлора Северного городского кладбища города Ростов-на-Дону. *Трансформация экосистем* **8** (1), 108–122. https://doi.org/10.23859/estr-230809

Поступила в редакцию: 09.08.2023
Принята к печати: 21.09.2023
Опубликована онлайн: 21.02.2025

Introduction

Cemeteries are a mandatory and specific element of the city areas, playing an important ecosystem role in addition to its main function (Sallay et al., 2023).

Cemeteries are anthropogenically transformed habitats with significantly modified vegetation (Baranova and Bralgina, 2015). On the one hand, transformed landscapes of cemeteries serve to preserve plant biodiversity (Löki et al., 2019; Nowińska et al., 2020), on the other hand, they are areas where the process of naturalization of exotic species is taking place (Czarna, 2016; Rutkovska et al., 2011).

The plant communities of cemeteries differ from other urban ecotopes by its high species diversity (Czarna, 2016; Trzaskowska and Karczmarz, 2013). The biodiversity here depends on the cemetery nature and size, environmental heterogeneity, type and intensity of management (Buchholz et al., 2016; Kowarik et al., 2016; McClymont and Sinnett, 2021). In these areas, native and alien species introduced into regional culture grow side by side. In urban landscaping, alien plants are mainly represented by species that have shown the highest resistance in new conditions; as a rule, they have a high potential for naturalization. Therefore, cultivated alien species especially influence the structure of plant communities in both cemeteries and adjacent areas (Ramula and Pihlaja, 2012).

Alien woody plants stand apart: as invaders, they can change greatly the appearance of plant communities in the areas, where woody life forms are poorly represented or completely absent (Kozlovsky et al., 2020; Mesacasa et al., 2022; Moyano et al., 2023; Nayak et al., 2023). Such territories include the steppe zone of southern Russia, including the Rostov Oblast.

The Northern city cemetery (NCC) of the Rostov-on-Don city is one of the largest in Europe. It has been founded in 1972; nowadays, its area is about 360 hectares.

The NCC flora has not been sufficiently studied. The woody plants of this cemetery were described in 2009 by the route survey without performing detailed analysis (Pokhilko, 2009). In total, 98 species of woody plants were identified in two city cemeteries (NCC and Verkhne-Gnilovskoe City Cemetery); this number exceeded the species diversity of most gardens and parks of the Rostov-on-Don city. The study aims to examine the composition of alien woody plant species, which spread spontaneously across the NCC. The objectives of this study were:

1. To study the species composition of woody plants in detail at the NCC;
2. To identify alien species of woody plants spreading spontaneously at the NCC;
3. To characterize quantitatively the process of spontaneous dispersal of alien woody plant species across the NCC.

Materials and methods

The climate of Rostov-on-Don is moderately continental and dry, with moderately mild winters and hot summers (Shver and Ivanchenko, 1987). The average annual air temperature is +8.9 °C. During the year, the average monthly air temperature varies from −5.7 °C in January up to +23.0 °C in July. The absolute minimum temperature reaches −33.0 °C, absolute maximum, +42.0 °C. Average annual precipitation is 548 mm. The total precipitation during the frost-free period is 270–300 mm.

The study was performed in the Northern city cemetery of the Rostov-on-Don city, Russia (N 47°18′33″ E 39°42′08″) in 2023. The cemetery consists of 225 quarters, each comprising 1000-In total, 18 native and 64 alien species of woody plants grow in the Northern city cemetery of the Rostov-on-Don city, Russia.

The cemetery occupies a very large area. Its relief is plain. The soils are of the zonal type, represented by ordinary chernozem. One part of the cemetery is located in a steppe area, the other part, on agricultural lands (here, shelterbelts are preserved). The woody plant diversity is very rich at the NCC (Pokhilko, 2009). Greening of burial sites was not regulated for a long time; the recommendation to avoid planting trees in the NCC was issued only in the early 2000s.

The tombstones have different designs and were constructed using different materials. This contributed to the formation of crevice habitats on the NCC territory, suitable for the settlement of small-seeded and moisture-loving species.

The burial sites have fences of various designs. Their presence and the dense arrangement of the burials made it virtually impossible to carry out centralized maintenance work on the cemetery plantings, including the removal of spontaneously dispersed woody plants. These works are mainly

carried out by individuals within the fence of the burials, while many burials are abandoned. The intensity of cemetery territory management is low. Enough time has passed since the cemetery was formed for spontaneously dispersed woody plants to reach the generative stage.

Thus, the NCC of the Rostov-on-Don city can be considered as a testing ground for studying the process of naturalization of exotic trees in typical conditions of the steppe zone in terms of relief, soil and climate, transformed by human ritual activity.

Before conducting the study, the entire cemetery area was divided into three zones (Fig. 1):

Zone A – burials since 1972. Woody vegetation has formed into a community similar to a typical forest, where the first and second tiers are clearly visible, and the crowns of the first tier are closed. The herbaceous cover is not expressed.

Zone B – burials since 1992. Woody vegetation has formed into communities similar to sparse forests (a type of forest with low tree density, the crowns of the first tier are not closed), long-rhizome cereals predominate in the grass cover.

Zone C – burials since 2008. Woody plants have not formed communities, they are located far from each other; all of them have spontaneously dispersed, except for representatives of the former indigenous vegetation *Prunus spinosa* and *Rubus caesius.* The herbaceous cover is dominated by ruderal weeds and long-rhizome grasses.

We have studied woody plants growing on the entire territory of NCC by means of a detailed survey of randomly selected blocks. A total of 37 blocks were surveyed.

During the study, the taxa of the woody plants were identified (species cultivars were not taken into account), their ontogenetic stage (virginal (v) or generative (g)), abundance, and occurrence were assessed, and the origin of the samples in the cemetery was determined using dispersal method (Polevaya geobotanika, 1964). Self-seeding of woody plants (specimens up to two years of age) was not taken into account. The abundance of plants in a block was determined in three sample plots of 400 m^2 by counting the plants growing there. Then, the number of plants per hectare was recalculated. The species occurrence was calculated as the ratio of the number of blocks where it was found to the total number of blocks surveyed.

In order to determine the origin of woody plants, their age (correspondence to the time of burial) and the location of the plant (within or outside the fence, on or close to tombstones) were taken into account. In this way, spontaneously dispersed specimens (including those unintentionally spread by humans) were separated from plants planted on burial sites in purpose.

Results and discussion

During the study, 82 species of woody plants (planted on the burial site, spontaneously dispersed, and remnants of the vegetation that originally grew in the area) were identified in the NCC, including 64 species (78%) of alien woody plants and 18 species (22%) belonging to the indigenous flora. Rosaceae family dominated by the number of species (22 species), followed by Cupressaceae (7), Sapindaceae (6), Oleaceae (5); Fabaceae, Pinaceae, and Salicaceae (4 species each); Ulmaceae (3); Betulaceae, Bignoniaceae, Caprifoliaceae, and Vitaceae (2 species each). *Prunus* genus was represented most diversely (11 species), followed by *Acer* and *Juniperus* (5 species each); *Populus*, *Sorbus*, and *Ulmus* (3 species each); *Betula*, *Crataegus*, *Fraxinus*, *Picea*, *Pinus*, and *Robinia* (2 species each).

Aboriginal species were *Acer campestre* L., *Acer tataricum* L., *Cornus sanguinea* L., *Crataegus* × *kyrtostyla* Fingerh., *Fraxinus excelsior* L., *Juniperus sabina* L., *Ligustrum vulgare* L., *Lonicera tatarica* L., *Populus alba* L., *Prunus spinosa* L., *Prunus tenella* Batsch, *Pyrus communis* L., *Quercus robur* L., *Rosa canina* L., *Rubus caesius* L., *Salix alba* L., *Ulmus laevis* Pall., *Ulmus minor* Mill. Of these, *A. campestre*, *A. tataricum*, *C.* × *kyrtostyla*, *F. excelsior*, *L. vulgare, L. tatarica*, *P. communis*, *R. canina*, and *U. minor* dispersed spontaneously throughout the cemetery by seeds.

Alien species were represented by *Acer negundo* L., *A. platanoides* L., *A. pseudoplatanus* L., *Aesculus hippocastanum* L., *Ailanthus altissima* (Mill.) Swingle, *Amelanchier spicata* (Lam.) K. Koch, *Berberis aquifolium* Pursh, *Betula pendula* Roth, *B. pubescens* Ehrh., *Buxus sempervirens* L., *Campsis radicans* (L.) Seem., *Catalpa speciosa* Teas, *Celtis occidentalis* L., *Clematis vitalba* L., *Crataegus submollis* Sarg., *Forsythia* × *intermedia* Zabel, *Fraxinus pennsylvanica* Marshall, *Gleditsia triacanthos* L., *Gymnocladus dioica* (L.) K. Koch, *Hibiscus syriacus* L., *Hippophae rhamnoides* L., *Juglans regia* L.,

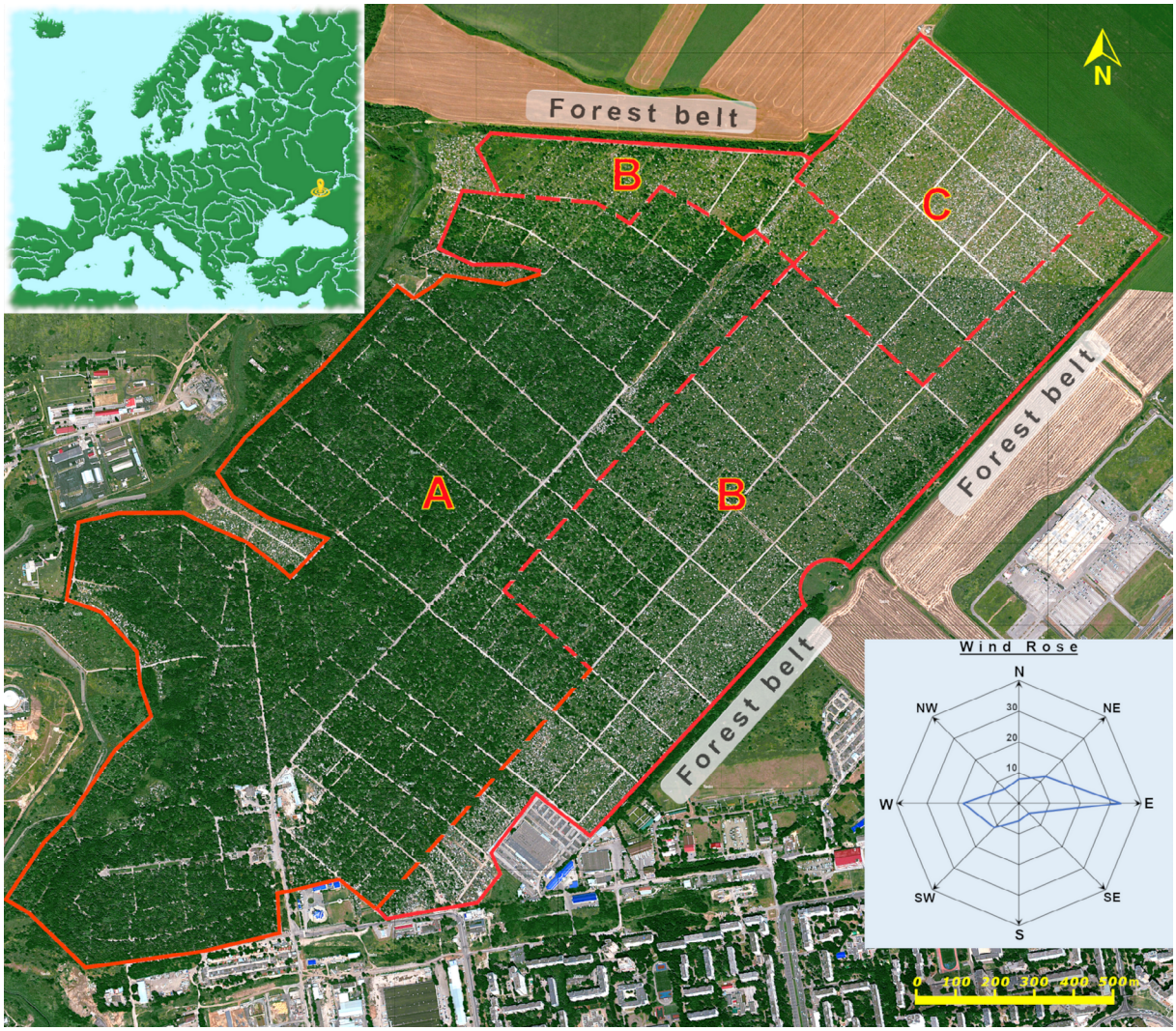

Fig. 1. Zones of the Northern city cemetery of Rostov-on-Don city, Russia.

Juniperus chinensis L., *J. communis* L., *J. scopulorum* Sarg., *J. virginiana* L., *Malus domestica* Borkh., *Morus alba* L., *Parthenocissus vitacea* (Knerr) Hitchc., *Philadelphus coronarius* L., *Picea abies* (L.) H. Karst., *P. pungens* Engelm., *Pinus nigra* J.F. Arnold, *P. sylvestris* L., *Platycladus orientalis* (L.) Franco, *Populus deltoides* W. Bartram ex Marshall, *Populus simonii* Carrière, *Prunus armeniaca* L., *P. cerasifera* Ehrh., *P. cerasus* L., *P. mahaleb* L., *P. padus* Mill., *P. serotina* Ehrh., *P. tomentosa* Thunb., *P. triloba* Lindl., *P. virginiana* L., *Rhamnus cathartica* L., *Rhus typhina* L., *Robinia pseudoacacia* L., *R. viscosa* Michx. ex Vent. (1800), *Sorbus aria* (L.) Crantz, *S. aucuparia* L., *S. intermedia* (Ehrh.) Pers., *Spiraea* × *vanhouttei* (Briot) Carrière, *Symphoricarpos albus* (L.) S.F. Blake, *Syringa vulgaris* L., *Tamarix tetrandra* Pall. ex M. Bieb., *Thuja occidentalis* L., *Tilia cordata* Mill., *Ulmus pumila* L., *Viburnum opulus* L., *Vinca minor* L., *Vitis vinifera* L., and *Yucca filamentosa* L.

According to chorological analysis of alien woody plants in NCC, the species of North American origin dominated (36%), followed by European species (22%), East Asian and Chinese species (13%), and Eurasian species (11%) (Table 1). A small number of tree species originated from Asia Minor, the Caucasus, the Mediterranean, Central and Middle Asia, the Far East, and Japan.

Probably, *C.* × *kyrtostyla*, *P. spinosa*, *P. tenella*, *R. caesius*, and *R. canina* represent the remains of the indigenous flora that originally grew in this area. *R. canina* is also represented by specimens of rootstocks remaining after the dying of varietal roses. These species are characteristic of the ravine

vegetation of the Lower Don (Zozulin, 1992). Most likely, the aboriginal species *A. tataricum*, *U. laevis*, *U. minor*, and alien species *A. negundo*, *A. altissima*, *F. pennsylvanica*, *M. alba* have settled here from the adjacent plantings, since they are not considered ornamental plants by the local population. It is most likely that *P. armeniaca*, *P. cerasus*, *P. communis*, and *V. vinifera*, seed generations of varietal samples of apple, pear, plum, and grape were unintentionally brought to the cemetery by people (anthropochory). These woody plants are found outside the fences of the burials (or in places inconvenient for planting within the fences), along the roadsides, next to forest shelterbelts. Other species were planted on the burials as ornamental plants. It should be noted that the local population does not have an established assortment of mourning plants.

There are 21 alien species spontaneously dispersing through seeds in the cemetery. Interestingly, 90% of them are trees. The abundance and occurrence of alien tree species spontaneously dispersing in the NCC are presented in Table 2.

The following alien species have spread throughout the cemetery: *A. negundo*, *A. platanoides*, *A. altissima*, *C. occidentalis*, *F. pennsylvanica*, *J. regia*, *M. domestica*, *M. alba*, *P. armeniaca*, *P. cerasifera*, *P. mahaleb*, and *U. pumila*; of these, the most abundant and frequent are *A. negundo*, *A. altissima*, *C. occidentalis*, *F. pennsylvanica*, *P. mahaleb*, and *U. pumila.* These species are also characteristic of other ecotopes of Rostov-on-Don and are classified as invasive species (Kozlovsky et al., 2011, 2016; Pokhilko, 2009).

High abundance of different-aged specimens of *M. alba* and *U. pumila* is a distinctive characteristic of the NCC area. At the same time, *M. alba* is represented mainly by male specimens (about 70%), which are more drought-resistant than female ones (Delfan Azari et al., 2018). The seeds of these species do not have a dormant state and germinate immediately after falling. This occurs in the first half of summer during the dry period, so in local conditions, these species disperse only along floodplains (Nikolaeva, 1985). The dispersal of *M. alba* and *U. pumila* in the plain territory of the NCC occurs due to the presence of specific crevice habitats. During rains, water quickly penetrates into the cracks that appear between tombstones (or fences) and the adjacent soil. The seeds that fall into them are buried rather than lying on the surface; the plants do not experience a deficiency of nutrients, as is observed in the cracks of the walls and roofs of buildings, concrete and other surfaces (Fig. 2). In addition, these places accumulate large quantities of seeds of anemochorous species (*A. negundo*, *A. altissima*, *F. pennsylvanica*, and *U. pumila*), because gravestones and fences trap them during dispersal. The presence of specific crevice habitats explains the isolated finds of virginal specimens *of C. speciosa*, *J. virginiana*, *P. padus*, *S. aucuparia*, and *S. intermedia.*

Table 1. Geographic origin of alien woody plant species presented at the Northern city cemetery of Rostov-on-Don city, Russia.

Geographic origin	Number of species	%
North America	23	36
Europe	14	22
East Asia and China	8	13
Eurasia	7	11
Asia Minor and the Caucasus	3	5
Mediterranean	2	3
Central and Middle Asia	2	3
Far East and Japan	1	2
Unknown	4	6
Total	**64**	**100**

Table 2. Alien species of woody plants spontaneously dispersing across the Northern city cemetery of Rostov-on-Don city, Russia. Species occurrence was calculated separately for each zone.

Species	NCC zone	Abundance, ind./ha	Occurrence, %	Ontogenetic stage
A. negundo	A	30–40	100	v, g
	B	21–40	92	v, g
	C	3–10	63	v, g
A. platanoides	A	41–60	100	v, g
	B	11–20	46	v, g
	C	1–2	25	v
A. pseudoplatanus	A	11–20	75	v
	B	5–10	8	v
A. altissima	A	41–60	83	v, g
	B	11–20	62	v, g
	C	1–2	13	v
C. occidentalis	A	30–40	100	v, g
	B	11–20	85	v, g
	C	11–20	75	v, g
E. angustifolia	C	1–2	13	v, g
F. pennsylvanica	A	41–60	75	v, g
	B	21–40	77	v, g
	C	3–10	75	v, g
G. triacanthos	B	11–20	38	v, g
	C	1–2	38	v, g
J. regia	A	11–20	75	v
	B	11–20	77	v, g
	C	1–2	50	v
M. domestica	A	11–20	58	v, g
	B	11–20	46	v, g
	C	3–10	88	v, g
M. alba	A	11–20	67	v, g
	B	11–20	85	v, g
	C	3–10	75	v, g

Species	NCC zone	Abundance, ind./ha	Occurrence, %	Ontogenetic stage
P. armeniaca	A	5–10	75	v
	B	5–10	62	v, g
	C	1–2	50	v, g
P. cerasifera	A	11–20	67	v, g
	B	5–10	8	v, g
	C	1–2	38	v, g
P. cerasus	A	11–20	83	v, g
	B	5–10	23	v, g
P. mahaleb	A	11–20	33	v, g
	B	5–10	69	v, g
	C	3–10	100	v, g
P. padus	B	5–10	15	v, g
P. serotina	B	5–10	23	v, g
R. pseudoacacia	A	5–10	25	v, g
	B	5–10	8	v, g
S. vulgaris	A	41–60	100	v, g
	B	5–10	31	v
U. pumila	A	30–40	92	v, g
	B	21–40	77	v, g
	C	1–2	63	v, g
V. vinifera	A	5–10	15	v, g

The other characteristic of the NCC area is the high proportion of species that are unintentionally spread by humans. These are *M. domestica*, *P. armeniaca*, *P. cerasifera*, and *P. cerasus.* In the cemetery zone C, where no woody plants are planted intentionally, these species are highly abundant (Table 2).

High abundance and occurrence of the North American species *Celtis occidentalis* is another characteristic feature of the NCC. This species is represented here by specimens of different ages, from juvenile to middle-aged generative individuals. Irradiation center of *C. occidentalis* is possibly the largest specimen found in Quarter 42A (Zone A), the age of which corresponds to the age of the cemetery. In local conditions, this species regularly and abundantly bears fruit, the fruits are readily eaten by birds, the seeds have a period of physiological dormancy, germinating in the spring. Based on the results of the introduction test, this species is classified as a highly winter-hardy and drought-resistant plant (Kozlovsky et al., 2000). No mention of *C. occidentalis* could be found in literary sources as an invasive species in Russia, except for data for the Rostov Oblast (Kozlovsky et al., 2020).

The plain conditions of the territory and the presence of obstacles (gravestones and fences) contributed to the widespread distribution of the anemochorous species *F. pennsylvanica* throughout the

Fig. 2. . Characteristic location of *Fraxinus pennsylvanica* (**A)** and *Ulmus pumila* (**B)** at burials.

NCC. The original source of its seeds were forest shelterbelts that remained from agricultural lands. The dynamics of the population of this species with increasing distance from the shelterbelt is shown at Fig. 3.

Another feature of the NCC woody flora is a large number of species that spread across the territory exclusively by vegetative means: *A. spicata*, *B. aquifolium*, *C. radicans*, *C. vitalba*, *H. rhamnoides*, *P. vitacea*, *R. typhina*, *R. viscosa*, *S. albus*, and *V. minor* (Fig. 4). The absence of generative offspring in these species is associated with the absence of viable seeds (*C. radicans*, *R. typhina*, and *V. minor*), weak drought resistance of seedlings *(A. spicata*, *C. vitalba*, and *H. rhamnoides*), the absence of dissemination agents due to composition of fruits (*P. vitacea* and *S. albus)*. Of these, species with high vegetative mobility may pose an invasive danger if they enter favorable conditions (for example, a floodplain): *C. vitalba* (Kozlovsky et al., 2017), *H. rhamnoides*, *R. typhina*, and *V. minor.* Previously, *P. vitacea* invasion was registered in floodplain forests (Kozlovsky et al., 2020; Saksonov et al., 2017).

The presence of spontaneously dispersing species across the NCC area, their abundance, frequency, and age structure in different areas indicate that the cemetery's woody flora experiences a dynamic state. It can be predicted that over time, the areas of the last burials (zone C) will be populated by woody plants that successfully compete with herbaceous vegetation, taking advantage of the presence of specific crevice habitats. The floristic composition of zone A of the cemetery in the coming decades will presumably change significantly due to the death of planted woody plants that are unable to renew

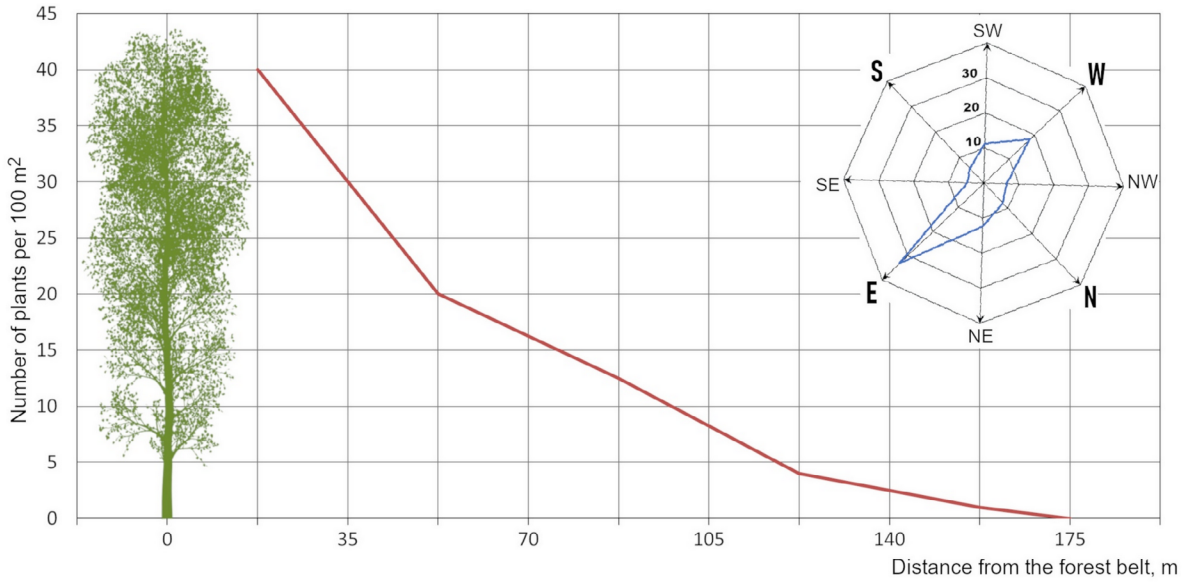

Fig. 3. Dynamics of changes in the number of specimens of anemochorous species *Fraxinus pennsylvanica* as they move away from the seed source (forest shelterbelt).

Fig. 4. Vegetative distribution of *Parthenocissus vitacea* for several burials.

themselves by seeds or vegetatively, since massive death of *B. pendula*, *B. pubescens*, *B. sempervirens*, *P. abies*, *S. aucuparia*, and some other species is already observed. In this regard, it should be noted that the duration of ontogenesis of long-lived tree species (*F. excelsior*, *G. triacanthos*, *P. orientalis*, *Q. robur*, *R. pseudoacacia,* etc.) does not exceed 100 years in the Rostov-on-Don city (Kozlovsky et al., 2009). Thus, the woody flora will be unified throughout the cemetery. Species capable of spontaneous dispersal will predominate in the composition of the plantings, and vegetatively mobile plants will also be preserved (such as *P. vitacea*, *S. vulgaris*, *V. minor* and some others).

Conclusions

In total, 18 native and 64 alien species of woody plants grow in the Northern city cemetery of the Rostov-on-Don city, Russia.

Among the alien species that have spontaneously settled throughout the cemetery, *A. negundo*, *A. platanoides*, *A. altissima*, *C. occidentalis*, *F. pennsylvanica*, *J. regia*, *M. domestica*, *M. alba*, *P. armeniaca*, *P. cerasifera*, *P. mahaleb*, and *U. pumila* dominate by abundance and frequency of occurrence.

The presence of specific crevice habitats facilitates the sustainable reproduction of tree species in the cemetery area.

The main ways of seed dispersal of woody plants across the NCC are anemochory (*A. negundo*, *A. platanoides*, *A. altissima*, *F. pennsylvanica*, etc.), ornithochory (*C. occidentalis*, *J. regia*, *M. alba*, *P. mahaleb*, etc.) and anthropochory (*M. domestica*, *P. armeniaca*, *P. cerasifera*, *P. cerasus)*.

Woody flora experiences a dynamic state. We assume that its species composition will unify across all cemetery zones over time. Such alien species as *A. negundo*, *A. altissima*, *C. occidentalis*, *F. pennsylvanica*, and *U. pumila* will dominate in the woody flora.

References

Baranova, O.G., Bralgina, E.N., 2015. Klassifikatsiia gorodskikh mestoobitanii gorodov Udmurtskoi Respubliki [Classification of urban habitats of towns of the Udmurt Republic]. *Vestnik Udmurtskogo universiteta. Seriya Biologiya. Nauki o Zemle [Bulletin of the Udmurt University. Biology series. Earth sciences]* **25** (1), 34–39. (In Russian).

Buchholz, S., Blick, T., Hannig, K., Kowarik, I., Lemke, A. et al., 2016. Biological richness of a large urban cemetery in Berlin. Results of a multi-taxon approach. *Biodiversity Data Journal* **4,** e7057. https://doi.org/10.3897/BDJ.4.e7057

Czarna, A., 2016. Vascular plant flora in the Cytadela cemeteries in Poznań (Poland). *Acta Agrobotanica* **69** (4), 1695. http://dx.doi.org/10.5586/aa.1695

Delfan Azari, N., Rostami Shahraji, T., Gholami, V., Hashemi Garmdareh, S.E., 2018. The effect of different irrigation levels on growth of fruitless Mulberry (*Morus alba* fruitless) in green space of Tehran. *Silva Balcanica* **19** (1), 21–31.

Kowarik, I., Buchholz, S., von der Lippe, M., Seitz, B., 2016. Biodiversity functions of urban cemeteries: Evidence from one of the largest Jewish cemeteries in Europe. *Urban Forestry & Urban Greening* **19**, 68–78. https://doi.org/10.1016/j.ufug.2016.06.023

Kozlovsky, B.L., Ogorodnikov, A.Ya., Ogorodnikova, T.K., Kuropyatnikov, M.V., Fedorinova, O.I., 2000. Tsvetkovye drevesnye rasteniia Botanicheskogo sada Rostovskogo universiteta [Angiosperms woody plants of the Botanical Garden of Rostov University]. Starye Russkie, Rostov-on-Don, Russia, 144 p. (In Russian).

Kozlovsky, B.L., Ogorodnikova, T.K., Kuropyatnikov, M.V., Fedorinova, O.I., 2009. Assortiment drevesnykh rastenii dlia zelenogo stroitel'stva v Rostovskoi oblasti [Assortment of woody plants for planting of greenery in the Rostov region]. South Federal Unibersity, Rostov-on-Don, Russia, 416 p. (In Russian).

Kozlovsky, B.L., Kuropiatnikov, M.V., Fedorinova, O.I., 2011. Ekologo-biologicheskaia kharakteristika drevesnykh rastenii urbanoflory Rostova-na-Donu [Ecological and biological characteristics of woody plants of the urban flora of Rostov-on-Don]. *Izvestiia Irkutskogo gosudarstvennogo universiteta. Seriia "Biologiia. Ekologiia" [Bulletin of Irkutsk State University. Series "Biology. Ecology"]* **4** (2), 38–43. (In Russian).

Kozlovsky, B.L., Kuropyatnikov, M.V., Fedorinova, O.I., Sereda, M.M., Kapralova, O.A., Dmitriev, P.A., Varduni, T.V., 2016. Adventive tree species in urban flora of Rostov-on-Don. *Biological bulletin of Bogdan Chmelnitskiy Melitopol state pedagogical university* **6** (3), 430–437.

Kozlovsky, B.L., Fedorinova, O.I., Kuropiatnikov, M.V., Dmitriev, P.A., 2017. *Clematis vitalba* L. – potentsial'no invazionnyi vid dlia Rostovskoi oblasti [*Clematis vitalba* L. is a potentially invasive species for the Rostov region]. *Ukrainian Journal of Ecology* **7** (4), 116–124. (In Russian).https://doi.org/10.15421/2017_94

Kozlovskiy, B.L., Fedorinova, O.I., Kuropyatnikov, M.V., 2020. Invasion of the *Parthenocissus inserta* (Kern.) K. Fritsch. in floodplain forests of Rostov Oblast. *Russian Journal of Biological Invasions* **11**, 41–46. https://doi.org/10.1134/S2075111720010075

Löki, V., Deák, B., Lukács, A.B., Molnár, V.A., 2019. Biodiversity potential of burial places – a review on the flora and fauna of cemeteries and churchyards. *Global Ecology and Conservation* **18** (1), e00614. https://doi.org/10.1016/j.gecco.2019.e00614

McClymont, K., Sinnett, D., 2021. Planning cemeteries: their potential contribution to green infrastructure and ecosystem services. *Frontiers in Sustainable Cities* **3**, 789925. https://doi.org/10.3389/frsc.2021.789925

Mesacasa, L., Macagnan, L.B., Fiaschi, P., Dechoum, M.S., 2022. Effects of time since invasion and control actions on a coastal ecosystem invaded by non-native pine trees. *Ecological Solutions and Evidence* **3** (1), e12138. https://doi.org/10.1002/2688-8319.12138

Moyano, J., Zamora-Nasca, L.B., Caplat, P., García-Díaz, P., Langdon, B. et al., 2023. Predicting the impact of invasive trees from different measures of abundance. *Journal of Environmental Management* **325** (B), 116480. https://doi.org/10.1016/j.jenvman.2022.116480

Nayak, R., Krishnaswamy, J., Vaidyanathan, S., Chappell, N.A., Singh, R., 2023. Invasion of natural grasslands by exotic trees increases flood risks in mountainous landscapes in South India. *Journal of Hydrology* **617** (A), 128944. https://doi.org/10.1016/j.jhydrol.2022.128944

Nikolaeva, M.G., Razumova, M.V., Gladkova, V.N., 1985. Spravochnik po prorashchivaniyu pokoyashchihsya semyan [Handbook on germination of dormant seeds]. Nauka, Leningrad, USSR, 347 p. (In Russian).

Nowińska, R., Czarna, A., Kozłowska, M., 2020. Cemetery types and the biodiversity of vascular plants – A case study from south-eastern Poland. *Urban Forestry & Urban Greening* **49**, 126599. https://doi.org/10.1016/j.ufug.2020.126599

Polevaya geobotanika [Field geobotany], 1964. Lavrenko, E.M., Korchagina, A.A. (eds.). USSR Academy of Sciences, Moscow – Leningrad, USSR, 530 p. (In Russian).

Pokhil'ko, L.O., 2009. Ekologicheskie printsipy formirovaniia assortimenta drevesnykh rastenii v ozelenenii g. Rostova-na-Donu [Ecological principles for the formation of an assortment of woody plants in the landscaping of the city of Rostov-on-Don]. *PhD in Biology thesis abstract.* Rostov-on-Don, Russia, 25 p. (In Russian).

Ramula, S., Pihlaja, K., 2012. Plant communities and the reproductive success of native plants after the invasion of an ornamental herb. *Biological Invasions* **14** (10), 2079–2090. https://doi.org/10.1007/s10530-012-0215-z

Rutkovska, S., Pučka I., Novicka, I., 2011. Analysis of invasive flora in cemetery territories of the city of Daugavpils. *Proceedings of the 8th International Scientific and Practical Conference* "*Environment. Technologies. Resources."* **2**, 344–351. http://dx.doi.org/10.17770/etr2011vol2.1001

Saksonov, S.V., Rakov, N.S., Vasyukov, V.M., Senator, S.A., 2017. Chuzherodnye rasteniya v lesnykh soobshchestvakh Srednego Povolzh'ya: sposoby disseminatsii i stepen' naturalizatsii [Alien plants in forest communities of the Middle Volga Region: dissemination and degree of naturalization]. *Sanarskii nauchnyi vestnik [Samara Journal of Science]* **6** (2), 78–83. (In Russian). https://doi.org/10.17816/snv201762115

Sallay, Á., Tar, I.G., Mikházi, Z., Takács, K., Furlan, C., Krippner, U., 2023. The role of urban cemeteries in ecosystem services and habitat protection. *Plants* **12** (6), 1269. https://doi.org/10.3390/plants12061269

Shver, Ts.A., Ivanchenko, T.E. (eds.), 1987. Klimat Rostova-na-Donu [Climate of Rostov-on-Don]. Gidrometeoizdat, Leningrad, Russia, 233 p. (In Russian).

Trzaskowska, E., Karczmarz, K., 2013. Spontaneous vascular flora of selected cemeteries in Lublin and the surrounding area. *Acta Agrobotanica* **66** (2), 107–122. https://doi.org/10.5586/aa.2013.028

Zozulin, G.M., 1992. Lesa Nizhnego Dona [Forests of the Lower Don]. Rostov University Publishing House, Rostov-on-Don, USSR, 208 p. (In Russian).

Список литературы

Баранова, О.Г., Бралгина, Е.Н., 2015. Классификация городских местообитаний городов Удмуртской Республики. *Вестник Удмуртского университета. Серия Биология. Науки о Земле* **25** (1), 34–39.

Зозулин, Г.М., 1992. Леса Нижнего Дона. Издательство Ростовского университета, Ростов-на-Дону, СССР, 208 с.

Козловский, Б.Л., Огородников, А.Я., Огородникова, Т.К., Куропятников, М.В., Федоринова, О.И., 2000. Цветковые древесные растения Ботанического сада Ростовского университета. Старые Русские, Ростов-на-Дону, Россия, 144 с.

Козловский, Б.Л., Огородникова, Т.К., Куропятников, М.В., Федоринова, О.И., 2009. Ассортимент древесных растений для зеленого строительства в Ростовской области. ЮФУ, Ростов-на-Дону, Россия, 416 с.

Козловский, Б.Л., Куропятников, М.В., Федоринова, О.И., 2011. Эколого-биологическая характеристика древесных растений урбанофлоры Ростова-на-Дону. *Известия Иркутского государственного университета. Серия «Биология. Экология»* **4** (2), 38–43.

Козловский, Б.Л., Федоринова, О.И., Куропятников, М.В., Дмитриев, П.А., 2017. *Clematis vitalba* L. – потенциально инвазионный вид для Ростовской области. *Ukrainian Journal of Ecology* **7** (4), 116–124. https://doi.org/10.15421/2017_94

Николаева, М.Г., Разумова, М.В., Гладкова, В.Н., 1985. Справочник по проращиванию покоящихся семян. Наука, Ленинград, СССР, 347 с.

Полевая геоботаника, 1964. Лавренко, Е.М., Корчагин, А.А. (ред.). АН СССР, Москва – Ленинград, СССР, 530 с.

Похилько, Л.О., 2009. Экологические принципы формирования ассортимента древесных растений в озеленении г. Ростова-на-Дону. *Автореферат диссертации на соискание ученой степени кандидата биологических наук*. Ростов-на-Дону, Россия, 25 с.

Саксонов, С.В., Раков, Н.С., Васюков, В.М., Сенатор, С.А., 2017. Чужеродные растения в лесных сообществах Среднего Поволжья: способы диссеминации и степень натурализации. *Самарский научный вестник* **6** (2), 78–83. https://doi.org/10.17816/snv201762115

Швер, Ц.А., Иванченко, Т.Е. (ред.), 1987. Климат Ростова-на-Дону. Гидрометеоиздат, Ленинград, Россия, 233 с.

Buchholz, S., Blick, T., Hannig, K., Kowarik, I., Lemke, A. et al., 2016. Biological richness of a large urban cemetery in Berlin. Results of a multi-taxon approach. *Biodiversity Data Journal* **4,** e7057. https://doi.org/10.3897/BDJ.4.e7057

Czarna, A., 2016. Vascular plant flora in the Cytadela cemeteries in Poznań (Poland). *Acta Agrobotanica* **69** (4), 1695. http://dx.doi.org/10.5586/aa.1695

Delfan Azari, N., Rostami Shahraji, T., Gholami, V., Hashemi Garmdareh, S.E., 2018. The effect of different irrigation levels on growth of fruitless Mulberry (*Morus alba* fruitless) in green space of Tehran. *Silva Balcanica* **19** (1), 21–31.

Kowarik, I., Buchholz, S., von der Lippe, M., Seitz, B., 2016. Biodiversity functions of urban cemeteries: Evidence from one of the largest Jewish cemeteries in Europe. *Urban Forestry & Urban Greening* **19**, 68–78. https://doi.org/10.1016/j.ufug.2016.06.023

Kozlovsky, B.L., Kuropyatnikov, M.V., Fedorinova, O.I., Sereda, M.M., Kapralova, O.A., Dmitriev, P.A., Varduni, T.V., 2016. Adventive tree species in urban flora of Rostov-on-Don. *Biological bulletin of Bogdan Chmelnitskiy Melitopol state pedagogical university* **6** (3), 430–437.

Kozlovskiy, B.L., Fedorinova, O.I., Kuropyatnikov, M.V., 2020. Invasion of the *Parthenocissus inserta* (Kern.) K. Fritsch. in floodplain forests of Rostov Oblast. *Russian Journal of Biological Invasions* **11**, 41–46. https://doi.org/10.1134/S2075111720010075

Löki, V., Deák, B., Lukács, A.B., Molnár, V.A., 2019. Biodiversity potential of burial places – a review on the flora and fauna of cemeteries and churchyards. *Global Ecology and Conservation* **18** (1), e00614. https://doi.org/10.1016/j.gecco.2019.e00614

McClymont, K., Sinnett, D., 2021. Planning cemeteries: their potential contribution to green infrastructure and ecosystem services. *Frontiers in Sustainable Cities* **3**, 789925. https://doi.org/10.3389/frsc.2021.789925

Mesacasa, L., Macagnan, L.B., Fiaschi, P., Dechoum, M.S., 2022. Effects of time since invasion and control actions on a coastal ecosystem invaded by non-native pine trees. *Ecological Solutions and Evidence* **3** (1), e12138. https://doi.org/10.1002/2688-8319.12138

Moyano, J., Zamora-Nasca, L.B., Caplat, P., García-Díaz, P., Langdon, B. et al., 2023. Predicting the impact of invasive trees from different measures of abundance. *Journal of Environmental Management* **325** (B), 116480. https://doi.org/10.1016/j.jenvman.2022.116480

Nayak, R., Krishnaswamy, J., Vaidyanathan, S., Chappell, N.A., Singh, R., 2023. Invasion of natural grasslands by exotic trees increases flood risks in mountainous landscapes in South India. *Journal of Hydrology* **617** (A), 128944. https://doi.org/10.1016/j.jhydrol.2022.128944

Nowińska, R., Czarna, A., Kozłowska, M., 2020. Cemetery types and the biodiversity of vascular plants – A case study from south-eastern Poland. *Urban Forestry & Urban Greening* **49**, 126599. https://doi.org/10.1016/j.ufug.2020.126599

Ramula, S., Pihlaja, K., 2012. Plant communities and the reproductive success of native plants after the invasion of an ornamental herb. *Biological Invasions* **14** (10), 2079–2090. https://doi.org/10.1007/s10530-012-0215-z

Rutkovska, S., Pučka I., Novicka, I., 2011. Analysis of invasive flora in cemetery territories of the city of Daugavpils. *Proceedings of the 8th International Scientific and Practical Conference* "*Environment. Technologies. Resources."* **2**, 344–351. http://dx.doi.org/10.17770/etr2011vol2.1001

Sallay, Á., Tar, I.G., Mikházi, Z., Takács, K., Furlan, C., Krippner, U., 2023. The role of urban cemeteries in ecosystem services and habitat protection. *Plants* **12** (6), 1269. https://doi.org/10.3390/plants12061269

Trzaskowska, E., Karczmarz, K., 2013. Spontaneous vascular flora of selected cemeteries in Lublin and the surrounding area. *Acta Agrobotanica* **66** (2), 107–122. https://doi.org/10.5586/aa.2013.028