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Assessment of the ecological status of street plantings in Balashikha city, Moscow region

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Abstract. The level of urbanization in the world is increasing by the year. In Russia, it amounts to about 75%. Green spaces play a leading role in the process of maintaining the ecological balance of urbanized territories. One of the main sources of environmental pollution in cities are cars. Monitoring the condition of woody plants in outdoor plantings is an important part of assessing the condition of urban systems. The purpose of the work is to conduct a comprehensive assessment of the ecological state of tree plantations in the street plantings of Balashikha, a city, which is a part of Moscow agglomeration. The study was carried out in 2019–2021 in 20 streets of Balashikha. The species composition, the vital state of tree and shrub vegetation in street plantings according to Alekseev's methodology and winter hardiness according to Lapin and Sidneva's methodology were revealed. The following results were obtained: in the street plantings of Balashikha there are 21 species of trees and shrubs, the average age of tree plantations is 30–40 years, the most common ones are *Acer negundo* L., *Acer platanoides* L., *Tilia cordata* Mill., single – *Acer tataricum* L., *Pinus sylvestris* L., *Sorbus aucuparia* (L.) Gaertn., *Ulmus laevis* Pall. In order to maintain sustainable development, it is necessary to change the strategy of urban greening (implement a more diverse species composition, conduct monitoring studies involving not only utilities, but also researchers dealing with urban ecology problems, apply modern maintenance technologies. Recommendations are given on the introduction of new types of woody plants for outdoor plantings to improve the ecological situation in Balashikha.

Keywords: Green spaces, urban ecosystems, species richness, vital condition, winter hardiness, occurrence

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Оценка экологического состояния зеленых насаждений в г. Балашиха, Московская область

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Аннотация. Уровень урбанизации в мире растет с каждым годом. В России он составляет около 75 %. Зеленые насаждения играют ведущую роль в процессе поддержания экологического баланса урбанизированных территорий. Одним из основных источников загрязнения окружающей среды в городах являются автомобили. Мониторинг состояния древесных растений в уличных посадках является важной частью оценки состояния урбоэкосистем. Цель работы – провести комплексную оценку экологического состояния древесных насаждений в уличных посадках г. Балашиха как города, входящего в Московскую агломерацию. Исследование осуществлялось в 2019–2021 гг. на 20 улицах г. Балашиха. Был выявлен видовой состав, жизненное состояние древесно-кустарниковой растительность в уличных посадках по методикам Алексеева и зимостойкость по методике Лапина и Сидневой. В результате полученных исследований получились следующие результаты: в уличных посадках г. Балашиха используется 21 вид деревьев и кустарников, средний возраст древесных насаждений 30–40 лет, наиболее часто встречаются *Acer negundo* L., *Acer platanoides* L., *Tilia cordata* Mill., единично – *Acer tataricum* L., *Pinus sylvestris* L., *Sorbus aucuparia* (L.) Gaertn., *Ulmus laevis* Pall. Для поддержания устойчивого развития необходимо изменить стратегию озеленения города (использовать более разнообразный видовой состав, проводить мониторинговые исследования с привлечением не только коммунальных служб, но и ученых, занимающихся проблемами экологии городов, применять современные технологии в работах по уходу. Даны рекомендации по введению новых видов древесных растений для уличных посадок в целях улучшения экологической ситуации в г. Балашиха.

Ключевые слова: зеленые насаждения, урбоэкосистемы, видовое разнообразие, жизненное состояние, зимостойкость, встречаемость

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Introduction

Urbanization is a complex and constantly increasing process. It is one of the key issues nowadays, not only from an environmental point of view, but also from an economic, social, etc. perspective. “In 1900, 14% of the total population lived in the cities of the world, 12 of which were million-plus”. On the eve of the 21st century. 45% of the world population became urban, there were approximately 2.4 thousand large cities (over 100 thousand inhabitants each) and over 200 million-plus cities” [1].

Urbanization leads not only to the growth of cities, but also to a change in the entire environment. An urban heat island appears with a change in climatic parameters: the temperature in the city is 1–4 °C higher than in suburban areas, the number of sunny days decreases, the transparency of the atmosphere decreases, an “urban breeze” appears, precipitation increases, etc. The soil structure changes, instead of natural ecosystems, natural-anthropogenic or anthropogenic ones appear [2–6].

To maintain the ecological balance in urban areas, a system of green spaces is being created. They perform various functions: sanitary and hygienic, recreational, aesthetic, architectural and artistic, ecosystem. At the same time, woody plants are the main component of green spaces [7–10].

Tree plantations used in street plantings have a special role. They protect cities from harmful substances, dust, noise, etc. Therefore, the identification of the ecological state of this group of green spaces is relevant.

Under the influence of unfavorable environmental factors, plants form a response, which is expressed in a change in growth, the death of shoots, a decrease in immunity, the spread of various pests and diseases. This is expressed in a change in the state of life, which characterizes the degree of resistance of plants in an urbanized environment.

Monitoring studies of the vital state of plants, especially trees and shrubs, are carried out in many large cities and megapolises [5, 11–19]. Whereas in the satellite cities, such studies are practically not carried out. But they are also important and relevant.

Balashikha is the largest city in the Moscow Region and is a part of the Moscow agglomeration. Balashikha was founded in 1830, received the city status in 1939. At the moment, it is part of the Balashikha urban district with a population of more than 500 thousand inhabitants. The climate is temperate continental with frosty, snowy winters and humid, relatively warm summers and well-defined transitional seasons. It is due to the position of the region in the center of the Russian Plain [20].

Balashikha is a significantly transformed natural-technogenic system. This is a large industrial center with a significant number of enterprises (more than

100 large and medium ones). "The main environmental problems are associated with the presence of large foci of technogenic pollution of the natural environment, which spread in a radial direction from Moscow along the main transport routes" [20–21].

"In the urban district of Balashikha, there are 22.4 kg/year of pollutants per 1 city dweller, while the regional average is 33.2 kg/year. It should be noted that in the urban district of Balashikha, there is an extremely low use of dust and gas cleaning equipment by industrial enterprises (the share of pollutants captured is only 1.3%), which indicates significant air pollution by emissions of harmful substances. The main emitted pollutants are: carbon monoxide, nitrogen dioxide, nitrogen oxide. These 3 substances account for about 70% of all emissions from stationary sources. The remaining emissions (about 30%) include the following substances: soot, sulfur dioxide, hydrogen sulfide, kerosene, petroleum gasoline and other substances. 3259.65 tons/year of harmful substances (100%) come from all recorded sources of air pollution in the municipality, including: from stationary sources of pollution (industrial enterprises and boiler houses) – 2513.6 tons/year (77%); from mobile sources of pollution (road transport) 746.057 tons/year (23%). In general, the environmental situation in the urban district of Balashikha in terms of air pollution can be described as threatening. The main sources of atmospheric air pollution are large industrial enterprises in the city of Balashikha. Also, a significant contribution to air pollution is made by the main roads of the urban district" [20].

The purpose of this work is to assess the species diversity and vital status of woody plants in street plantings in the city of Balashikha.

To achieve this goal, the following tasks were set: a comprehensive assessment of the ecological state of woody plants in street plantings in Balashikha, the study of species diversity and the development of recommendations for optimizing the species composition of tree plantations.

Materials and Methodology

The species affiliation of trees and shrubs was determined according to the standard method [22–23]. The assessment of the vital state of tree plantations was carried out in 2019–2021 according to the method of diagnosing the condition of trees and forest stands [24]. The state scores of individual trees of each species were determined according to the scale proposed in this method. Next, we calculated the average state score for each type of tree (K_i) and the overall coefficient (K_{total}) of the state of street plantings in the city of Balashikha.

When assessing the distribution of species in the researched area, the following categories of occurrence were identified: "very often" – the number of individuals of this species is more than 10% of the total number of individuals; "often" – from 1 to 10%; "rarely" – from 0.1 to 0.9%; "very rarely" – from 0.01 to 0.09%. Species encountered in a single specimen are referred by us to the category "single" [25].

One of the important indicators of the state of plantings is winter hardiness. This parameter is also relevant for the Moscow region. The assessment of winter

hardiness was carried out on the basis of a scale developed in the Main Botanical Garden of the Academy of Sciences (GBS AN) [26]: I – plants do not freeze over; II – no more than 50% of the length of annual shoots freezes over; III – freezes from 50 to 100% of the length of annual shoots; IV – not only annual, but also older shoots are frosted over; V – the above-ground part freezes up to the snow cover; VI – the entire above-ground part is frosted over; VII – the plant freezes out entirely.

The study of street tree plantations in Balashikha was carried out in 2019–2021 along the Lenin Avenue and the streets of 40 years of Victory, Bykovsky, Zarechnaya, Zvezdnaya, Kalinin, Karbyshev, Karl Marx, Krupeshina, Krupskaya, Nekrasov, Association, Pobeda, Pushkinskaya, Soviet, Sportivnaya, Tekstilshchikov, Tereshkova, Chekhov, Julius Fuchik.

Results

As a result of the study of tree plantations in ordinary plantings in the city of Balashikha, 21 taxa were identified. 12 species and hybrids (57.14%) are introduced, and 9 (42.86%) are wild.

The identified taxa belong to 10 families: *Salicaceae* – 5 species (23.83%), *Aceraceae* – 3 (14.29%), *Fabaceae* – 2 (9.52%), *Oleaceae* – 2 (9.52%), *Rosaceae* – 2 (9.52%), *Tiliaceae* – 2 (9.52%), *Ulmaceae* – 2 (9.52%), *Betulaceae* – 1 (4.76%), *Hippocastanaceae* – 1 (4.76%), *Pinaceae* – 1 (4.76%).

The category “very often” includes – *Acer negundo* L., *Acer platanoides* L., *Tilia cordata* Mill.; “often” – *Populus balsamifera* L., *Tilia platyphyllos* Scop.; “rarely” *Aesculus hippocastanum* L., *Betula pendula* Roth., *Populus* × *berolinensis* (C. Koch) Dipp., *Populus tremula* L., *Robinia pseudoacacia* L., *Ulmus pumila* L.; “very rare” – *Caragana arborescens* Lam., *Fraxinus excelsior* L., *Fraxinus pennsylvanica* March., *Malus domestica* Bork, *Populus alba* L., *Salix fragilis* L.; “single” – *Acer tataricum* L., *Pinus sylvestris* L., *Sorbus aucuparia* (L.) Gaertn., *Ulmus laevis* Pall. (Figure 1).

The age of most tree plantations is about 30–40 years. Although in recent years, new plants have been planted in the city, including along the streets.

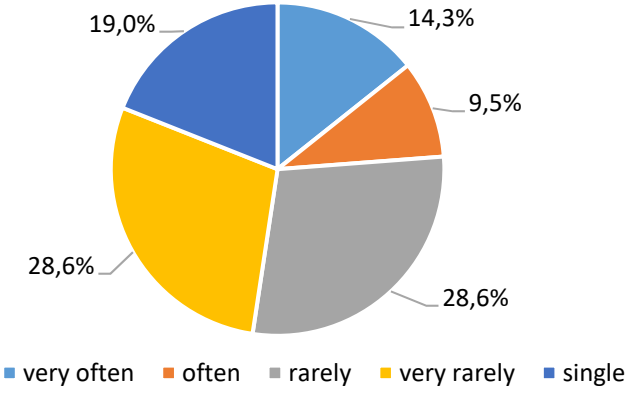

Figure 1. Occurrence of species in street plantings in Balashikha

An assessment of the vitality of 4128 trees on 19 streets and 1 avenue was carried out. 872 (21.12%) of the examined trees are classified as "healthy" (Figure 1). 1251 (30.31%) belong to the "weakened" category and have minor damage (drying of branches, thinning of the crown). The share of "very weakened" trees accounts for the majority – 1460 (35.37%). In such specimens, a significant drying of the branches, dry top, marginal and central chlorosis were noted, and in some places the bark died off. This is especially true for *Acer negundo* L. 523 (12.67%) trees belong to the category of "drying out". Such plants have drying of branches throughout the crown, lack of growth, the presence of marginal and central chlorosis, insect damage, sometimes on the trunks – the fruiting bodies of marsupial and basidiomycetes. 22 trees (0.53%) of woody plants with no leaves, with peeling bark or no bark, were classified as "completely dry". Among this group are trees belonging to *Acer negundo L., Acer platanoides L., Fraxinus excelsior L., Tilia cordata Mill.*

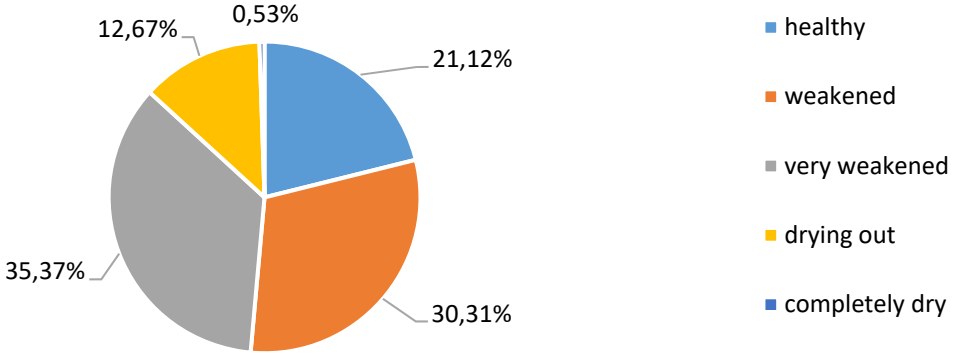

Figure 2. Percentage of vital state groups of woody plants in Balashikha street plantings

Table 1. **Average scores (K_i) of the condition of tree species and the overall condition coefficient (K_{total}) of the studied green spaces in Balashikha**

№	Species	K_i	K_{total}
1	Common birch (*Betula pendula* Roth.)	1.26	2.29
2	European white elm (*Ulmus laevis* Pall.)	1.73	
3	Chinese elm (*Ulmus pumila* L.)	1.56	
4	Brittle willow *(Salix fragilis* L.*)*	1.38	
5	Siberian pea shrub (*Caragana arborescens* Lam.)	2.69	
6	Scarlet chestnut (*Aesculus hippocastanum* L.)	2.54	
7	Norway maple (*Acer platanoides* L.)	3.68	
8	Tatarian maple (*Acer tataricum* L.)	1.3	
9	Maple ash (*Acer negundo* L.)	3.32	
10	Large-leaved linden (*Tilia platyphyllos* Scop.)	2.74	
11	Little-leaved linden (*Tilia cordata* Mill.)	2.38	
12	Black locust (*Robinia pseudoacacia* L.)	1.73	
13	Rowanberries (*Sorbus aucuparia* (L.) Gaertn.)	2.37	
14	Balsam poplar (*Populus balsamifera* L.)	2.61	
15	White poplar (*Populus alba* L.)	3.76	
16	Berlin poplar (*Populus × berolinensis* (C. Koch) Dipp.)	1.47	
17	Trembling poplar (*Populus tremula* L.)	1.21	
18	Common pine (*Pinus sylvestris L.*)	1.17	
19	Domesticated apple (*Malus domestica* Borkh.)	2.85	
20	Common ash (*Fraxinus excelsior* L.)	3.48	
21	Black ash (*Fraxinus pennsylvanica* March.)	2.86	

Table 1 shows the average state scores for each type of tree (K_i) and the overall coefficient (K_{total}) of the state of the studied green spaces in Balashikha. It was revealed that the trees along the roads of Balashikha are weakened (K_{total} = 2.29), requiring preventive measures, pruning and sanitization. Although, it should be noted that in recent years, work has begun on the replacement of shrunken and drying tree plantations along the roads.

When assessing winter hardiness, it was found that all species represented in the street plantations of Balashikha belong to group I – the plants do not freeze, except for *Robinia pseudoacacia L.*, in which freezing of annual shoots was observed by approximately 40%. Accordingly, this species can be attributed to group II in terms of winter hardiness.

Discussion

Tree plantations of street plantings in the city of Balashikha suffer from vehicle pollution, deterioration of the agronomic and geochemical properties of the soil. At the same time, there is often no care for these plantations, with the exception of heavy pruning at the places where electric lines pass, which, in turn, weakens the plants and further leads to the drying of these specimens. Due to the drying of plants, the planting structure is disturbed, therefore, the sanitary and hygienic function of green spaces is reduced.

It is possible to improve the condition of tree plantations along the roads of Balashikha due to several factors: change the strategy of planting greenery in the city (use a more diverse species composition, conduct monitoring studies involving not only utilities, but also scientists involved in urban ecology, apply modern technologies in the work care, etc).

In the street plantings of Balashikha, it is necessary, if possible, to plant shrubs. It is recommended to use a more diverse assortment of trees and shrubs in terms of species composition. It is proposed to use the following species of trees and shrubs: *Larix decidua* Mill., *L. sibirica* Ledeb., *Picea pungens* Engelm., *Juniperus sabina* L., *Acer rubrum* L., *A. saccharinum* L., *Berberis thunbergii* DC., *B. vulgaris* L., *Cotoneaster lucidus* Schlecht., *Crataegus monogyna* Jacg., *C. pentagyna* Waldst. et Kit., *C. pinnatifida* Bunge, *C. submollis* Sarg., *Juglans mandshurica* Maxim., *Ligustrum vulgare* L., *Padus maackii* (Rupr.) Kom., *Syringa reticulata subsp. amurensis* (Rupr.) *P.S. Green & M.C. Chang,* different species and hybrids of Malus Hill. and *Spiraea* L. These species have successfully acclimatized and tolerate urban conditions well [27–28].

Conclusions

As a result of the analysis of the conducted studies, the following conclusions can be drawn:

1. The species composition of woody plants used in street plantings in Balashikha is limited and consists of 21 species from 10 families. The uniformity of the presented taxa reduces the stability of ecosystems. The vital state of plants is deteriorating.

2. In the street plantings of Balashikha, 3 species of woody plants are most widely distributed: *Acer negundo* L., *Acer platanoides* L., *Tilia cordata* Mill., which is only 14.3% of the total number of identified species.

3. It was revealed that most of the presented plants are weakened, despite their young age (30–40 years), therefore they cannot fully perform the sanitary-protective function, and, therefore, maintain the ecological balance of the urban ecosystem.

4. Most species are winter-hardy in the conditions of Balashikha. Only in *Robinia pseudoacacia* L. frosting of one-year-old shoots is observed – 40%.

5. It is proposed to expand the range of woody plants used. 17 species of trees and shrubs that have successfully passed acclimatization and tolerate urban conditions well are recommended for urban plantations.

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