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The condition of green spaces in the central part of the city of Yekaterinburg

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Abstract. The article deals with the availability of public green spaces in the city of Ekaterinburg and its Central Planning District. We discuss the composition, condition of plants, and planting density in parks, garden squares and boulevards. We also discuss the negative phenomena affecting the general condition of green areas and their functions. We have analysed the main species used in landscaping and made suggestions for improving the situation.

1. Introduction

The city of Yekaterinburg is the administrative center of the Ural Federal District and the Sverdlovsk Region. This is a large industrial metropolis and at the same time the cultural capital of the Urals. In terms of the population size, it is one of the largest cities in Russia.

Yekaterinburg is a compact polycentric city; the boundaries of its administrative regions have developed historically. The growth of the city mostly occurred from the center to the periphery. The center of Yekaterinburg began to form in the late 18th - the first half of the 19th century. In the 19th century, the city's landscaping system was rapidly developing: the network of the first boulevards and garden squares organically fitted into the regular structure of the city center [1]. The main compositional axis of the city was adorned by a boulevard on the Main Avenue (now Lenin Avenue), and later (in the 20th century) the second compositional axis of the city was formed – the water-green diameter – the Iset River with recreation areas along it. These two axes are the basis of the green framework of the city.

The green framework of Yekaterinburg is formed by gardens, parks, garden squares and boulevards, and the main function of the “lungs of the city” is performed by forest parks located on the periphery [2]. In the framework of modern projects of intensive development and modern transformations of urban areas, the task of improving the comfort of the living environment should come to the fore [3]. The transformations associated with the reconstruction of old parks, garden squares and boulevards lead to significant, but not always positive, changes in the urban environment and in the appearance, structure and condition of landscape objects that have been formed over decades.

2. Methods and Materials

The article considers the public facilities of the Central Planning District (hereinafter referred to as CPD) of the city of Yekaterinburg: 6 parks, 11 garden squares and 1 boulevard. An inventory was carried out at all sites on the basis of the Regulations; the sanitary condition, the density of planting, and the type of spatial structure were studied. To determine the sanitary condition, a 6-point scale was



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used [4]. The type of spatial structure (TSS) was determined by the classification of L M Fursova and V A Agaltsova as closed, half-open and open, with a canopy closeness from 0.6 to 1.0; 0.3 to 0.5 and less than 0.3, respectively [5, 6].

3. Results and Discussion

The city of Yekaterinburg occupies an area of 1,143 km²; it is the administrative center of the Sverdlovsk region. It is divided into seven administrative districts (figure 1). The central part of the city is characterized by a high concentration of various types of socio-economic activities, is the historically established core of the city, and is located in several administrative districts. These are the most significant urban areas with a high building density and number of visits, both by residents and guests of the city.

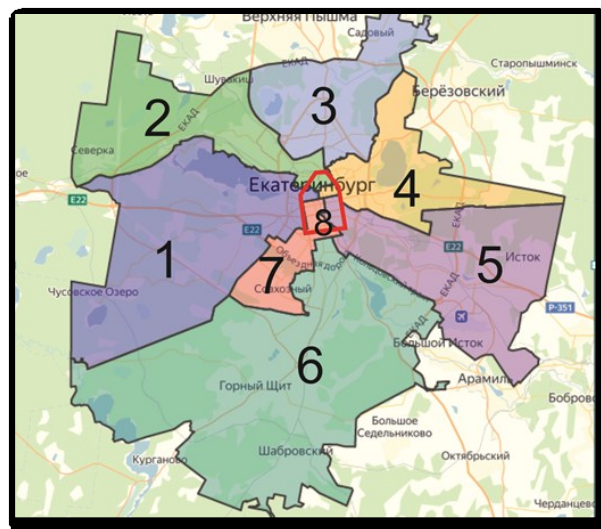


Figure 1. Districts of Yekaterinburg.
Administrative: 1) Verh-Isetskij; 2) Zheleznodorozhnyj; 3) Ordzhonikidzevskij; 4) Kirovskij; 5) Oktyabr'skij; 6) Chkalovskij; 7) Leninskij. *Planning:* 8) Central.

The General Development Plan until 2035 provides for the division of Yekaterinburg into 57 planning districts. The historically formed core of the city will be included in one planning area, Central. Its allocation, first of all, should affect the situation with the availability of public green spaces, since the population density of the area is 10312 people/km², which is 8 times higher than that of the city as a whole [7]. In 2010, the average population density in the city was 2687.6 people/km², but after the adjoining villages adjacent to the city, the figure dropped to 1297 people/km².

In the CPD with a very high population density, significant measures should be taken to preserve, restore and create new green areas of common use. The area of green spaces per person in the city and in the CPD is nearly the same, and amounts to 5.2 and 5.3 m², respectively, excluding street green areas. This indicator varies across the administrative districts, from 2.1 to 7.9 m²/person, which is clearly less than the recommended by SNIP 2.07.01-89* [8]. And only in one district the indicator is more than 10 m²/ person, which is due to the presence in this area of a large forest park, which includes a culture and recreation park.

Figure 2 shows the location of parks, garden squares and boulevards within the boundaries of the CPD. The area of the public green spaces is 67 hectares, which is 5.4% of the total area of the District. The area per person is 5.3m², which is not sufficient. There are six parks with a total area of 37 hectares, the sizes of which vary from 2.1 to 13.1 hectares. More than 20 hectares are occupied by

garden squares, but not all of them have official status, and therefore, it is likely that some of the objects will decrease in size or will be converted to other uses in the future.

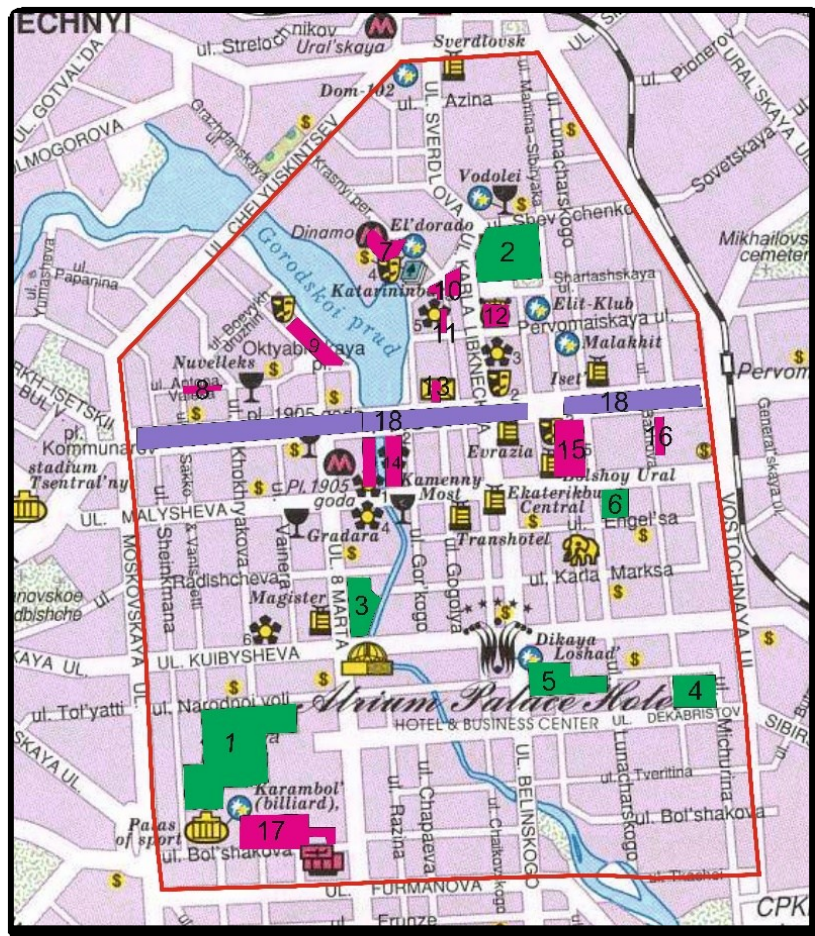


Figure 2. Public green spaces of the CPD of the city of Yekaterinburg. *Parks:* 1) The Green Grove; 2) Kharitonovskii Garden; 3) Dendrological Park; 4) Park of 50th anniversary of Soviet power; 5) Park named after Pavlik Morozov; 6) Park named after Engels. *Garden Squares:* 7) Square named after Kandelia; 8) Square named after Kuptsov Agafurovykh; 9) Garden on the Labour Square; 10) UNESCO square; 11) Square of the Literature Quarter; 12) Vainera Garden; 13) Square named after Popov; 14) Historical square; 15) Square at the Opera House; 16) Square on Michurina Street; 17) Square at the Sports Palace. *Boulevard:* 18) Boulevard on Lenina Street.

3.1. Parks

The characteristics of the parks are presented in table 1. All of them are unique, varying in time of creation, concept, purpose, organization of park space, structure and plant composition. Their differences emphasize the once thought-out system of urban gardening, providing the population with objects with different types of recreation. At the same time, the parks are similar in terms of their popularity and high visitor numbers.

The *Green Grove* is the oldest park in the city. The main purpose is recreation, long rest, and partially transit. The park with the area of 13 hectares was created in a forest area, where *Pinus sylvestris* L. still prevails (43.11%). The range of plants is wide and includes 20 species of trees and 10

species of shrubs. The second, after *Pinus sylvestris* L., most abundant species in the park is *Acer negundo* L. (20.67%). Tree stands are very dense in places. Plants are mostly old; the condition of *Acer negundo* L. and *Malus baccata* (L.) Borkh is poor and approaching 4 points (table 2). Clumps of off-shoots are found everywhere.

Table 1. Characteristics of the parks of the CPD.

Indicator	Green Grove	Kharitonov - skiy Garden	Dendro- logical Park	Park 50th anniversary of Soviet power	Park named after PavlikMorozov	Park named after Engels
Year of establishment	1790th	1826	1946	1960th	1931	1926
Area, ha	13.1	7.0	6.98	3.1	5.6	2.1
TSS	75	35	25	50	20	20
	10	45	50	40	40	50
	15	20	25	10	40	30
Number of trees, pcs/ha	250	202	252	294	138	230
Area balance, %	58	63	71.6	90.3	76.8	72.9
	25	12	14.3	6.4	10.7	12.8
	15	8	5.7	1.0	12.5	14.3
Number of plants, including	3832	1883	1814	979	1946	634
trees	3383	1676	1271	914	1134	347
shrubs	449	207	543	65	812	287
Number of species, including	30	43	59	32	37	24
trees	20	31	32	21	22	19
shrubs	10	12	27	11	15	6

Kharitonovsky Garden, founded in 1826, is an object of historical heritage. It has a long history; the park is almost two centuries old. It has undergone several transformations: from a city park to a children's park, and finally to a park in a residential area. Now its former significance is gradually being restored. A reconstruction project has been developed. In the park, unlike in the Green Grove, the proportion of deciduous species in the tree composition significantly exceeds the proportion of conifers, 90.8% and 9.2% (155 pcs), respectively. In total, 43 species are present: 31 tree species and 12 shrubs. Among deciduous species, trees of the second canopy layer (*Tilia cordata* Mill and *Acer negundo* L., 42.2%) dominate, to a lesser extent trees of the first (*Populus balsamifera* L. and *Betula pendula* Roth., 26.6%) and the third (*Malus baccata* (L.) Borkh and *Padus avium* Mill., 23%) canopy layers are represented. *Tilia cordata* Mill and *Populus balsamifera* L. are in satisfactory condition (2.7 and 2.6 points), the condition of *Malus baccata* (L.) Borkh is much worse. This is due to the fact that the oldest specimens of large trees were selectively removed, but no attention was paid to smaller ones.

The *Dendrological Park*, with an area of 7 hectares, is a popular vacation spot for residents and visitors of the city. In addition to recreation, its main purpose is educational, i.e. to acquaint visitors with a collection of local and exotic species. Here you can see species such as *Juglans manshurica* Maxim., *Betula pendula* f. *dalecarlica*, *Frangula alnus* Mill., *Pinus sibirica* (Rupr.) Mayr, *Quercus robur* L. and others. In the park there are about 60 species of trees and shrubs. *Tilia cordata* Mill. And *Betula pendula* Roth. are the most abundant species. *Picea abies* (L.) H. Karst. And *Picea pungens* Engelm. which occupy unusually large areas can be considered a special feature and a beauty of the

park. The park is carefully looked after, but the condition of the main species is deteriorating due to an old age and high recreation load. The average sanitary score of *Picea abies* (L.) H. Karst. And *Betula pendula* Roth. are 3.2 and 3.3, respectively; *Tilia cordata* Mill. is in a better condition.

Table 2. The sanitary condition of the prevailing species in the parks of the CPD.

Species	Share in the total composition, %	Sanitary state
<i>The Green Grove</i>		
<i>Pinus sylvestris</i> L.	43.1	3.3
<i>Acer negundo</i> L.	20.7	3.6
<i>Malus baccata</i> (L.) Borkh.	8.5	3.6
<i>Kharitonovsky Garden</i>		
<i>Tilia cordata</i> Mill	20.1	2.7
<i>Populus balsamifera</i> L.	13.9	2.6
<i>Malus baccata</i> (L.) Borkh.	11.3	3.3
<i>Dendrological Park</i>		
<i>Picea abies</i> (L.)	13.0	3.2
<i>Tilia cordata</i> Mill	9.3	2.7
<i>Betula pendula</i> Roth	7.8	3.3
<i>Park of the 50th anniversary of Soviet power</i>		
<i>Betula pendula</i> Roth	24.5	3.0
<i>Larix sibirica</i> L.	21.0	2.5
<i>Fraxinus pennsylvanica</i> Marsh.	12.7	4.0
<i>Park named after Pavlik Morozov</i>		
<i>Populus balsamifera</i> L.	26.6	4 (1.6 ^a)
<i>Malus baccata</i> (L.) Borkh	24.1	3.4 (2.0 ^a)
<i>Acer negundo</i> L.	12.4	3.4 (1.4 ^a)
<i>Park named after Engels</i>		
<i>Populus balsamifera</i> L.	15.5	2
<i>Malus baccata</i> (L.) Borkh	11.4	2.7
<i>Fraxinus pennsylvanica</i> Marsh.	8.4	2.5

^adata after reconstruction

The remaining three parks are of district importance and smaller in area; they were created during the development of the districts and have varying degrees of development.

The species diversity of the *Park of 50th anniversary of Soviet power* is represented by 32 species, of which 21 are trees and 11 are shrubs. 44.5% of the woody plants of the park are represented by line plantings of *Betula pendula* Roth. (224 pcs.) and *Larix sibirica* L. (192 pcs.). The best condition was observed in *Larix sibirica* L., 2.5 points (table 3), and unsatisfactory condition, in *Fraxinus pennsylvanica* Marsh., 4 points (table 3).

The species composition of the *Park named after Pavlik Morozov* is represented by 36 species, including 21 species of trees and 15 species of shrubs. Of the woody plants, *Populus balsamifera* L. (26.6%) and *Malus baccata* (L.) Borkh (24.1%) predominate. In 2014, reconstruction was carried out. The oldest and dying specimens were removed. The condition of plants have improved.

In the *Engels Park*, 24 species have been recorded, including 18 trees and 6 shrubs. Among them were *Populus balsamifera* L., *Betula pendula* Roth., *Fraxinus pennsylvanica* Marsh., *Tilia cordata* Mill., *Crataegus sanguinea* L., etc. The sanitary condition of the stands was satisfactory and varied from 2 to 2.7. The park is being prepared for reconstruction.

According to table 2, the most abundant species have different proportions in different parks and their sanitary condition varies substantially. For example, *Populus balsamifera* L. in the park named after Pavlik Morozov has an average sanitary score of 4, in the Kharitonovsky garden, 2.6 points, and in the Engels park, 2 points. One of the most common species not only in parks, but also in street

green areas is *Malus baccata* (L.) Borkh (from 8.5 to 24% of the composition of stands), which is most often in a weakened state (below 3 points). The worst condition is observed in *Populus balsamifera* L. after crown trimming and *Fraxinus pennsylvanica* Marsh. (4 points). The best condition was noted in *Tilia cordata* Mill, its average score was 2.7.

Table 3. Comparative analysis of the garden squares of the Central planning district by groups.

Name of the square				Creation time	Area, ha	Planting density, pcs/ha		TSS, %		
						trees	shrubs	closed	semi-open	open
1. "Old large"										
Historical Square				1973	6.9	53	1	0	25	75
Square at the Opera House				1960th	~ 3.0	98	79	52	31	17
Square at the Eternal Flame ^a				1930th	5.3	199	No data	50	30	20
Square at the Sports Palace				1970th	3.8	220	No data	55	15	30
2. "Old Small"										
Garden on the Labour Square				1935	~ 0.9	38	319	19	26	55
Square named after Popov ^b				1870th	~ 0.6	105	3	22	35	43
3. "New large"										
Square at the Drama Theater				1998	3.4	65	0	0	40	60
Square named after K. Babykin				2017	~1.6	75	188	0	30	70
4. "New small"										
Passage Square				2015	~ 0.5	26	1420	0	45	55
Square near the Railway Administration				2017	~ 1.0	10	2000	0	15	85
Railway Museum Square				2007	~ 0.3	0	0	0	0	100

^athe square has been demolished.

^bgarden squares after reconstruction.

In general, the average sanitary score of the prevailing species is below 3, which indicates a decrease in plant resistance and the need for constant care for them. So, for example, in the park named after Pavlik Morozov, after the reconstruction the sanitary score increased from 3.4-4.0 to 1.4-2.0 (table3) [9]. For the rest of the parks, reconstruction projects are ready or being developed.

The parks of the first half of the 20th century have a similar spatial structure (table 2). Closed spaces occupy 20-25%, and a proportion of semi-open and open spaces is high. For small regional parks in the Middle Urals, this is acceptable. The area of open spaces increases after the reconstruction of objects. This is clearly demonstrated by the change in the indicators of the park named after Pavlik Morozov. After reconstruction, open spaces increased to 40%, and the planting density decreased to 138 trees/ha, which is the lowest among the CPD parks.

In one of the oldest parks, the Green Grove, despite the ongoing efforts to remove dead and dangerous trees, the proportion of enclosed spaces is high (75%), and the stands are in need of reconstruction because of the large number of oppressed plants and thickened clumps of *Acer negundo* L.

The most problematic situation is in the park of the 50th anniversary of Soviet power with a high proportion of closed landscapes (50%), an average density of trees of 294 pcs/ha and a complex terrain that makes reconstruction difficult.

In Kharitonov Park, the ratio of the types of spatial structures (TPS) is close to the recommended one and the planting density is sufficient (202 pcs/ha). In the Dendrological park, the situation is also satisfactory, but the density of trees is high, 252 pcs/ha. High density of trees is caused by the presence of old-growth decorative stands and replenishment of the collection fund.

When the balance of the territory (table 1) is considered, the same trends are observed. In the regional parks, named after Engels and Pavlik Morozov, it is within the limits. The Green Grove has a high proportion of paths (25%), as opposed to the recommended 10%. In other parks, the balance is close to normal.

3.2. Garden Squares

In Yekaterinburg, there are 122 garden squares with a total area of 90.2 hectares. There are sixteen of them in the CPD. We analysed the state of 11 garden squares. The garden squares of Yekaterinburg (table 3) can be classified according to the time of creation as old (created at the beginning and middle of the 20th century) or new (late 20th - early 21st century), and according to the size as large (with an area of 2-3 ha or more) or small (with an area up to 1 ha).

The plant composition of garden squares is quite diverse. In the "old large" garden squares, it ranges from 12 to 20 species (16 on average) with a clear predominance of trees, from 75 to 98%. In the "old small", there are on average 6 species per object, also with a clear predominance of trees. In the "new" garden squares, both "large" and "small", the average number of species is 9–10. Shrubs (75–90%) are clearly predominant in the "small" garden squares. New tree species are also present, such as *Acer platanoides* "Deborah" and *Tilia europaea* "Pallida" [10].

The analysis of the spatial structure demonstrated that in the "new" garden squares that were created in later periods, there are no closed landscapes, and the area of open areas is growing steadily, especially in "small" garden squares. A significant decrease in planting density also occurs: on average in "new" garden squares it is 41 pcs/ha, and in "small" ones, only 12 pcs/ha. While in the group of "old" garden squares, the planting density is 99 pcs/ha, in the "old large" parks, on average, it reaches 143 trees/ha as opposed to the recommended 100 pcs/ha. The density of shrubs is the highest in "new" garden squares, especially in "small", up to 620–1420 pcs/ha. This is due to the replacement of lawns with dense curtains of shrubs.

3.3. Boulevards

The boulevard on the avenue named after Lenin is one of the oldest boulevards of the city, created at the beginning of the 19th century. It consists of two parts: an older western part and a younger eastern part created in the 20th century. The area of the boulevard is 2.5 hectares and the length is 1.6 km. The boulevard is not wide (10–12 m) and has lines of trees with a single-layer canopy structure. In the eastern part, *Fraxinus pennsylvanica* Marsh. and *Acer negundo* L. prevail, and in the western, after a recent reconstruction, *Tilia cordata* Mill. And *Picea obovata* Ldb. dominate a complex rhythmic planting structure. Currently, the species composition is quite diverse: there are 8 species of trees and shrubs. The sanitary state is mostly weakened (score 3) and only in *Tilia cordata* Mill. And *Malus baccata* (L.) Borkh is good (score 2). When shrubs are considered, *Syringa josikaea* Jacqfil. and *Amelanchier ovalis* Medik. are in the best condition.

The green area of the boulevard, in spite of the single-layer canopy structure, is dense (298 pcs/ha), and because of this has a protective function, in particular, noise reduction by 2 dB [11].

4. Conclusions

The spatial distribution of objects of the urban landscaping system is a reflection of the urban planning situation in Yekaterinburg. Parks and garden squares are unevenly distributed across the Central Planning District. In the central part of the city, the value of the indicator of territory greening is extremely low. At the same time, it is in the center that there is the largest influx of visitors during the daytime (employees, customers, guests of the city), so the real indicator will be even lower. When examining the landscape objects of the CPD, the following was revealed:

1. The parks of the CPD are in unsatisfactory condition: five out of six objects require serious reconstruction. This is due to the high proportion of enclosed spaces and high planting density, as well as a low score for the sanitary condition of plants. This applies especially to the old parks: the Green Grove, Kharitonovsky and the 50th anniversary of Soviet power. The Dendropark and park named after Engels are in relatively good condition.

2. After reconstruction, as a rule, the state of parks improves. The proportion of open spaces increases and planting density decreases, as happened, for example, in the park named after Pavlik Morozov. Such changes lead to a decrease in the protective functions of parks, their stability and decorativeness.

3. Due to their small areas and location near major highways, public gardens and boulevards of the CPD are among the most affected by the urban environment. The data obtained indicate that the garden squares created in the late 20th – early 21st centuries differ from the older ones in that the former have a significantly higher percentage of open spaces and have no closed spaces at all; they also have a low tree density and high density of shrubs. The same trend is observed in boulevards after their reconstruction. Therefore, we can talk about a decrease in the protective functions of the stands of garden squares and boulevards and a deterioration of the sanitary condition of stands during thinning.

4. Analysing species composition of different objects (taking into account the age of plants), it was found that *Tilia cordata* Mill., *Malus baccata* (L.) Borkh. and *Larix sibirica* L. are the most stable in the public urban green areas. When shrubs are considered, the most stable are *Cotoneaster lucidus* Schlecht., *Caragana arborescens* Lam., and *Crataegus sanguinea* Pall. The introduction of new decorative species and forms of trees and shrubs into urban objects is possible, but requires long-term observations and studies.

Therefore, in the frame work of the program of urban transformation in to a comfortable living environment, the planned activities should be aimed at the formation of a unified system of green spaces in the ecological frame work of the city. CPD, as the historical core of Yekaterinburg attracting a significant number of residents and visitors, is experiencing tremendous pressure. And the calculated rate of green spaces (5.3m²/person) is very low and will continue to decline. It is in the CPD, with a population density eight times higher than that of the city as a whole, that it is not only competent and timely to carry out agrotechnical measures to maintain sustainability and extend the longevity of plants, but, above all, to protect and create new facilities. Currently, an increase in the area, and, consequently, the number of public facilities for regular visits, that is, parks, garden squares, gardens, boulevards, is required.

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