Analysis of the Growing Conditions of the Growth of Woody Plants in an Urbanized Environment

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Abstract. Gardening of an industrial city is one of the necessary conditions for creating a comfortable environment. In a park or a public garden near a house, a person after a hard day’s work can take a breath of fresh air and put his thoughts in order, sitting in the shadow and listening to the birds singing in the crowns of trees. Also, parks are public spaces where you can make new acquaintances or just have a good time with your family. At the moment, there are many government projects aimed at improving the environmental situation of modern industrial cities and landscaping is not the last place in the list of necessary tasks. But first it’s necessary to assess the current state of the landscaping objects – the level of anthropogenic and development pressure, the degradation degree of plantations, etc. The current research work is devoted to the integral assessment of the quality of landscaping in Krasnoyarsk by dendroindication methods. The materials presented in this paper are the results of the intermediate stage of the research - analysis of the growing conditions of the growth of woody plants in an urbanized environment.

1. Introduction
A lot of attention has been paid to the current environmental situation in large industrial cities of Russia in recent years. Government, public organizations and citizens urge to be more careful with the environment. So, one of the most important documents at the state level, declaring the need to improve the environmental situation in industrial cities, is the Decree of the President of the Russian Federation dated May 7, 2018 No. 204 “On the national goals and strategic objectives of the development of the Russian Federation for the period up to 2024” [1]. In accordance with this document, it is required to develop national projects in twelve directions, including ecology. The national project “Ecology” is aimed at improving the efficiency of handling production and consumption wastes, reducing the level of air pollution in large industrial cities (this list includes Krasnoyarsk), improving the quality of drinking water and other vital components of the environment. In December 2018, the passport of the national project “Ecology” [2] was developed and approved, which established that by 2024 the level of air pollution will be assessed as “increased” [3].
2. Scientific significance
Indeed, according to the state reports "On the state and protection of the environment in the Krasnoyarsk Territory" [4], air pollution in the city of Krasnoyarsk for many years was characterized as "high" and "very high". The current ecological state of the urban environment formed with the onset of a sharp increase in industrial production in the early nineties of the 20th century and then a gradual decline. The minimum value of the IZA$_5$ (air pollution index) was recorded in 2000 and amounted to 8.4. Over the course of ten years, there has been an increase in the indicator to 23.75. Figure 1 shows the dynamics of the IZA$_5$ calculated for the five priority pollutants (in 2017, according to the monitoring results of the Central Siberian UGMS, priority pollutants were benzo (a) pyrene, formaldehyde, ammonia, nitrogen dioxide, suspended solids). For 2016 and 2017, the level of air pollution was characterized as “very high”, the exact value of the air pollution index is not presented.

![Figure 1. Dynamics of IZA$_5$ from 1988 to 2017.](image)

In order to improve the quality of the environment, along with work to reduce emissions of pollutants from stationary, mobile and autonomous sources of pollution, recultivation of industrial and household waste and improve the quality of drinking water, it is necessary to develop a landscaping complex in an industrial city.

In accordance with SP 42.13330.2016 [5], Krasnoyarsk belongs to the group of “largest” cities with a population of more than 1 million people, for which the specific value of the area of recreational areas of public use, taking into account all requirements, should be in the range from 20 to 21.6 m$^2$ person$^{-1}$. At the same time, according to the approved local standards of urban planning of Krasnoyarsk, the mandatory minimum level of provision with recreational areas must be at least 16 m$^2$ person$^{-1}$ [6], which is in the future more than 17.5 km$^2$. The design indicator is equal to the area of recreational areas without taking into account the requirements [5] of the natural area of the city and the presence of factories of the first danger class. It is obvious that at the moment there is a much smaller area of a green recreational zone per inhabitant of the city of Krasnoyarsk. The target specific indicator is planned to be achieved through the construction and reconstruction of landscaping objects, land recultivation after the demolition of abandoned factory areas and emergency housing, as well as the transformation of existing forest areas adjacent to microdistricts into forest parks. At the same time, existing landscapes should be maintained and improved, ensuring their spatial relationship with natural ecosystems.

In urban settlements it is necessary to provide for an uninterrupted system of recreational areas of public use and other open spaces in conjunction with the natural frame. One of the main structural elements of the landscaping system are specially protected natural areas. As part of the implementation of the project of the Krasnoyarsk Territory "Clean Air", it was decided to create the forest-park green area around the Krasnoyarsk.

The above-created projects and decisions indicate the interest and active participation of the government and the scientific community in solving the most urgent environmental problems of industrial cities.

3. Objects and methods of research
The city of Krasnoyarsk is almost four hundred years old and each epoch lived through left its mark on the development of the city. Passing through the streets, we can find preserved examples of landscape
architecture of the “old” city (manors, low-rise houses with personal adjoining territories), areas of the Soviet era (courtyards with the same type of geometry and a narrow range of plants used, etc.) and modern living territories with developed infrastructure. The landscaping system also underwent changes and met the requirements of the time. Based on this, you should pay attention to the uneven distribution of landscaping objects. At the present stage of development of the city, a comprehensive assessment of the quality of the greening system is required, which will become the starting point in creating a comfortable living environment for a person in a megapolis and improving the environmental situation.

At the moment, the authors are working on an integral assessment of woody plants by dendroindication methods at the landscaping objects in Krasnoyarsk, including plantations of picea obovata and picea pungens. These two species of spruce are chosen as dendroindicators due to the widespread use in gardening of the city of Krasnoyarsk and the ability of woody plants to respond to the exerted anthropogenic load [9, 10, 11].

To solve one of the tasks in the framework of the research work, a reconnaissance study of recreational areas of the city of Krasnoyarsk was carried out, the results of which required the determination of the types of growing conditions of woody plants. The type of growing conditions is a characteristic of landscape objects of a settlement with a uniform natural resource potential and a certain density of landscape- and urban-ecological factors and background pollution requiring equal economic investments and technological care [9]. Studies of the level of anthropogenic load on woody plants were carried out taking into account a set of factors of the ecological state of the urban environment, corresponding to a specific section of ecology [12, 13, 14]. The chosen method [9] allows a relatively quantitative assessment of the environmental stress of the territory in relation to the phytomedia in a single system of scoring negative factors.

4. Research results
At the preliminary stage, a study of the city was carried out in order to compile a variety of landscaping objects with plantations of picea obovata and picea pungens. In total, 133 landscaping objects were selected: 46 units in Sovetskiy District, 36 units in the Tsentral'nnyy District, 13 units in the Leninskiy District, 12 units each in the Kirovskiy and Oktyabr'skiy Districts, 7 units in the Zheleznodorozhnyy and Sverdlovskiy Districts of Krasnoyarsk. Further, landscaping objects are classified by function. In accordance with GOST 28329-89 [15], there are three types of green areas for functional purposes: landscaping objects of common use, landscaping objects of special use, landscaping objects of limited use. Table 1 presents data on the distribution of selected landscaping objects in the administrative districts of the city of Krasnoyarsk and the functional purpose.

Table 1. The distribution of landscaping objects in the administrative districts of the city of Krasnoyarsk and the functional purpose.

| Administrative district | The functional purpose of landscaping objects (units) |  |  |  |  |  |  |  |
|------------------------|-----------------------------------------------------|--|---|---|---|---|---|---|
|                        | Common use  | Limited use | Special use |  |  |  |  |  |
| Zheleznodorozhnyy      | 4           | 0           | 3           | 7 |
| Kirovskiy              | 8           | 2           | 2           | 12 |
| Leninskiy              | 7           | 2           | 4           | 13 |
| Oktyabr'skiy           | 2           | 4           | 6           | 12 |
| Sverdlovskiy           | 2           | 2           | 3           | 7 |
| Sovetskiy              | 12          | 9           | 25          | 46 |
| Tsentral'nnyy          | 18          | 9           | 9           | 36 |
| ∑                      | 53          | 28          | 52          | 133 |

At the next stage, the analysis of landscape and urban ecological characteristics and background pollution was carried out.
Landscape-ecological characteristics include the assessment of climatic and orographic factors: the compliance of ecological woody plant niches with the parameters of the landscape zone in which the landscaping object is located, the combination of the prevailing wind for a given region and street orientation, and the effect of the actual insolation power.

In terms of urban ecology, the assessment was carried out by road transport, urban planning, and recreational factors.

Currently, motor transport is one of the main contributors to the environmental pollution of an industrial city [4]. In addition to taking into account the power of the traffic flow near the planting object, additional factors were taken into account that increase the man-made load: the area of formation of traffic jams, sections of highways with poor quality of coating, chemical removal of snow from the roadway and storage under trees, and other important factors.

Urban factors combine the dependence of the density of tree plantings, the spatial distribution of plantings relative to nearby infrastructure facilities (artificial lighting, pumping stations, etc.) and buildings.

Factors such as: the direct impact of people on plantings, health, trampling, exceeding the maximum density of visits to the object of gardening, are taken into account in the assessment of resistance to recreational loads.

The background state of the environment of the city of Krasnoyarsk is formed by the combined impact of stationary (pollution sources of plants), mobile sources of pollution and autonomous sources of heat supply (the territory of individual residential construction). 1991 is a special year in the history of industrial development of Krasnoyarsk due to the fact that the maximum value of IZA was then recorded (63.6 points). Then, uncontrolled emissions from industrial plants exceeded all existing standards by dozens of times. According to the results of a comprehensive integrated assessment of the ecological state of the environment in Krasnoyarsk [14], in the areas where industrial enterprises are concentrated, the situation has reached a level close to an ecological catastrophe. Pollution of that level does not pass without a trace, and large arrays of plants degraded or died. Currently, the indicators have significantly decreased due to the strengthening of state environmental control over emissions into the environment from enterprises and the implementation of environmental protection measures. The average values of the ecological state in the territory of the planting facility are taken as the background state of the environment. But it should be borne in mind that at the local level, there are processes that bring or scatter pollutants. More comfortable conditions are formed in areas where planning solutions correspond to microclimatic and orographic situations - in large green areas, on the outskirts of the city close to natural landscapes, etc.

Four types of growing conditions are divided: “satisfactory” - I, “stressful” - II, “conflict” - III, “critical” - IV. Plantings on a landscaping site with “satisfactory” growing conditions experience minimal anthropogenic stress. Plant ontogenesis is close to growing under natural conditions. In "critical" growing conditions, the plants are under maximum load, metabolism is disturbed. Externally, the plant looks extremely unsatisfactory - asymmetry, disease, sparse crown [9, 10, 11].

The characteristics of landscaping objects in Krasnoyarsk according to the results of reconnaissance studies are presented in table 2.
Table 2. The characteristics of landscaping objects in Krasnoyarsk.

| Administrative district | Street name | The functional purpose of landscaping objects | The type of growing conditions of plants on landscaping objects (I / II / III / IV) |
|-------------------------|-------------|-----------------------------------------------|---------------------------------------------------------------------------------|
| Sverdlovskiy            | Yaryginskaya naberezhnaya | C | 1 / 2 / 1 / - |
|                         | 60 Let Oktjabrya | C | - / 1 / 1 / - |
|                         | Aleksandra Matrosova | L | - / - / - / - |
|                         | Sverdlovskaya | S, L | - / - / - / - |
|                         | Krasnoyarskiy rabochiy | S | - / - / 1 / - |
|                         | Pavlova | C | 1 / 2 / - / - |
|                         | Shichorsa | C, L | 1 / 2 / - / - |
|                         | Gruntovaya | C | - / 1 / - / - |
|                         | Kutuzova | C | - / 1 / - / - |
|                         | Akademika Vavilova | C | - / - / 1 / - |
|                         | Krasnoyarskiy rabochiy | C, S | - / - / 1 / - |
|                         | Tsentraľnyy proyezd | C, S | 1 / 1 / 1 / - |
|                         | Malakhovskaya | L | - / 1 / - / - |
|                         | Odesnaya | C | - / 1 / 1 / - |
| Kirovskiy                | Yunosti | C, S | - / 1 / 1 / - |
| 26 Bakinskikh komissarov | C, S, L | - / - / 1 / - |
| Festival'naya            | C | - / - / 1 / - |
|                         | Krasnoyarskiy rabochiy | C, S | - / - / 1 / - |
|                         | Yeleny Stasovoy | L | - / - / - / - |
|                         | Karbysheva | L | - / - / - / - |
|                         | Akademgorodok | L | - / - / - / - |
| Oktyabr'skiy            | Vil'skogo | L | - / - / 1 / 1 |
|                         | Svobodnaya | C, S | - / - / 1 / - |
|                         | Televizornaya | S | - / - / 1 / - |
|                         | Akademika Kirenskogo | S | - / - / 1 / - |
|                         | Vysotskaya | S | - / - / 1 / - |
|                         | Kainina | C | - / - / 1 / - |
|                         | Respubliki | C | - / - / 1 / - |
|                         | Karla Markska | C | - / - / 1 / - |
|                         | Bogradna | S | - / - / 1 / - |
|                         | Depovskaya | S | - / - / 1 / - |
|                         | Kopylova | C, S | - / - / 1 / - |
|                         | Konstitutsi SSSR | C | - / - / 1 / - |
|                         | Markovskogo | L | - / - / 1 / - |
|                         | Perenosna | C | - / - / 1 / - |
|                         | Suriyova | S | - / - / 1 / - |
| Zheleznodorozhnyy       | Dubrovinskogo | C, L | - / - / 1 / 1 |
|                         | Lenina | C, S, L | - / - / 1 / 1 |
|                         | Karla Markska | C, S, L | - / - / 1 / 1 |
|                         | Mira | C, S, L | - / 3 / 1 / 1 |
|                         | Novgorodskaya | C | - / - / - / - |
|                         | Vodop'yanova | S, L | 1 / 1 / 2 / - |
|                         | Aleksyeva | S, L | 1 / 2 / 3 / 1 |
|                         | Tereshkovoy | C | - / - / - / - |
|                         | Shumyatskogo | S | - / - / 1 / - |
|                         | Vzetnaya | S, L | - / - / 1 / - |
|                         | Vesny | C, S, L | - / - / 1 / 1 |
|                         | Komsomol'skiy | S | - / - / 1 / 1 |
|                         | Metallurgov | C, S | - / 2 / - / - |
|                         | Aviatorov | C, S | - / 2 / - / - |
|                         | Krasnodarskaya | C, S | - / 2 / - / - |
|                         | 9 Maya | C, S, L | - / 3 / - / - |
|                         | Molokova | C, S | - / 3 / 1 / - |
|                         | 3 Avgusta | S | - / - / - / - |
|                         | Baturina | C, S | - / - / 1 / 1 |
|                         | Partizana Zheleznaya | C, L | - / - / 2 / 2 |
|                         | 78 Dobrovoľ cheskoy brigady | S | - / - / 1 / - |

\( ^{a} \) C – landscaping objects of common use, S – landscaping objects of special use, L – landscaping objects of limited use.

\( ^{b} \) The number of landscaping objects of the appropriate type of plant growing conditions.
5. Conclusion

As part of the study, the following tasks were performed:

- survey of the territory of the city of Krasnoyarsk in order to compile an array of landscaping objects, including plantations of picea obovata and picea pungens;
- Landscaping objects classified by function;
- analysis of background environmental pollution, landscape and urban-environmental factors was carried out, according to the results of which four types of plant growing conditions were identified in Krasnoyarsk—“satisfactory” – I, “stressful” – II, “conflict” – III, “critical” – IV.

According to the results of the research, it was established that the best conditions for the growth of tree plantations are formed at the landscaping objects of common use of Zheleznodorozhnyy, Kirovskiy, Leninskiy, Sverdlovskiy and Tsentral'nyy districts of the city of Krasnoyarsk. These are mainly vast green areas with good air flow through prevailing winds, located at a considerable distance from major highways and industrial enterprises. In the Oktyabr'skiy and Sovetskiy districts are landscaping objects of limited use. In this case, greening facilities are located in the territories inside residential complexes, surrounded by multi-storey buildings and provided with high-quality care of plantings. Traffic intensity in the area is small.

For landscaping objects of special use located near the main highways of the city, a “critical” and “conflict” type of plant growing conditions in all districts of Krasnoyarsk (with the exception of Leninskiy district) are established. In the Leninskiy district, the majority of landscaping objects of common use are located along Krasnoyarskiy rabochiy Av., therefore they are also assigned a “critical” type of plant growing conditions.

All the results of the research are of high scientific and practical importance and will be used in further stages of research work.

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