Assessment of vitality state of green spaces in Krasnoyarsk

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Abstract. The urban environment with its corresponding complex of negative factors has a strong stressing effect on all components of the biota. Green spaces, being natural ‘green filters’, are among the first to respond to changes in the conditions of their growth. This response is evidenced, first of all, in the state of their crowns which includes the degree of the crown’s thinning, foliage (amount of needles), damage to leaf lamina, etc. The object of the current research are green spaces (parks, mini-parks, crops, forest stands) in Krasnoyarsk. Based on the inventory of tree and shrub plantings by the method of a complete recount on the selected sample areas of parks and mini-parks, the range of woody plants has been analyzed, and the vitality state of the examined plantings has been determined in accordance with characteristics of the crowns. As a result of the observations, it has been stated that the vitality state of the city’s green plantations is estimated as weakened and severely weakened.

1. Introduction

The ecology of major cities is the meaningful interaction of different activities aimed at improving the environment quality. To develop a plan of activities of how to raise the quality of city environment, the stakeholders need data on the level of the city territory pollution with transport and industrial emissions, information about the quantity and quality of green spaces in the city, and the data about the ability of these plantations to perform sanitary, hygienic and ecological functions in full.

There are several large industrial enterprises in Krasnoyarsk (LLC RUSAL Krasnoyarsk, JSC “Krasnoyarsk Cement”, JSC “Krasmash”, PLC “Krasstvetmet”, etc.), dozens of their maintenance facilities like boiler-houses and detached thermal power stations (JSC “Krasnoyarsk Thermal Power Station-1”, Thermal Power Station-2, Thermal Power Station-3) which are major air polluters. Expansion of the city, population growth and, as a consequence, increase of motor transport worsen the ecological situation even further.

Part of the environmental load can be reduced by cutting down on emissions. But at the same time the city experiences a shortage of green spaces. These green spaces fulfil crucial sanitary and hygiene functions and are also used extensively by the public for recreation. Modern requirements on urbanization of city areas raise demands on inner green spaces in order to improve the comfort and well-being of the urban environment.

Urban green spaces, parks, miniparks (public gardens) and forests within the territory of the city have long been subjects of numerous studies aimed at investigating the impact of the urban environment on trees [1-10].

Green spaces are an integral part of the urbanstructure. They influence the living conditions of the population by fulfilling a variety of socio-ecological (sanitary, hygienic, decorative, and planning) functions. Constant development of the city leads to a boost in the anthropogenic load on the existing...
plantations within the city, whereas the number of parks and public gardens barely rises. This has an adverse effect on the overall condition of plantations.

The aim of the present work is to examine the current sanitary and vitality status of green spaces on the basis of a detailed study of 22 sample plots during the 2019-2020 growing season, and to determine their species composition.

2. Methods and Materials
Krasnoyarsk is located in a river valley stretching 20-25 km along the Yenisei River, jutting out into the spurs of the Eastern Sayan which line the river valley from the west and south. These terrain features form the ecological environment of the city, and the green spaces in the city are its integral part. There are 11 city parks covering an area of 95 hectares and 68 miniparks covering 121 hectares. Urban forests are situated in the south-western part of the city.

During the vegetative season in 2019-2020, 13 monitoring plots in the largest parks and public gardens in the city were examined. Besides, we monitored 9 sample plots in forest stands of artificial and natural origin in the urban forests of the city (table 1).

Table 1. List of plantations surveyed.

| Number of sample plot | Origin of the green space | Prevailing tree species          |
|-----------------------|---------------------------|---------------------------------|
|                       | **parks, miniparks**      |                                 |
| 8                     | mixed                     | Balsam poplar                   |
| 10                    | plantations               | Scots pine                      |
| 19                    | plantations               | Balsam poplar                   |
| 31                    | plantations               | European white elm              |
| 36                    | plantations               | Balsam poplar                   |
| 37                    | plantations               | Balsam poplar                   |
| 45                    | plantations               | Silver birch                    |
| 61                    | plantations               | Balsam poplar                   |
| 62                    | plantations               | Siberian crab apple             |
| 63                    | plantations               | Siberian crab apple             |
| 64                    | plantations               | balsam poplar                   |
| 65                    | plantations               | Silver birch                    |
| 66                    | plantations               | Chinese elm                     |
|                       | **urban forests**         |                                 |
| 1                     | plantations               | Scots pine                      |
| 67                    | natural                   | Silver birch                    |
| 68                    | plantations               | Scots pine                      |
| 69                    | plantations               | Scots pine                      |
| 70                    | natural                   | Silver birch                    |
| 71                    | natural                   | Silver birch                    |
| 72                    | plantations               | Scots pine                      |
| 73                    | natural                   | Silver birch                    |
| 74                    | plantations               | Scots pine                      |

The surveyed plantations grow in different mesoclimatic areas of the city with differing levels of urban area pollution. The layout of the surveyed stands on the territory of Krasnoyarsk is given in figure 1.
In course of the study of plantations, the relative vitality state of trees and plantation as a whole was assessed. The evaluation of the condition of stands is based on the scale given in the Forest Sanitary Regulations [11, 12]; it was made as a continuous listing of trees and their classification into several categories, according to their state. The latter represent an integral assessment of the state of trees based on a set of visual attributes (crown density and its color, presence and proportion of dead branches, bark condition, etc.): I – no signs of weakening; II – weakened; III – severely weakened; IV – withered; V – fresh snags, VI – old snags; VII – wrecked trees.

To determine the relative vitality status (RVS) of a stand, V.A. Alekseev’s (1989) methodology was used for calculating the index $L_n$, %:

$$L_n = \frac{(100 \ n_1 + 70 \ n_2 + 40 \ n_3 + 5 \ n_4)}{N},$$

where, $L_n$ is the relative vitality of the stand derived from the number of trees (shrubs); $n_1$ – number of healthy trees or shrubs; $n_2$ – number of weakened trees or shrubs; $n_3$ – number of severely weakened trees; $n_4$ – number of dying trees or shrubs; $N$ – total number of trees and shrubs surveyed in the area (including snags). 100, 70, 40 and 5 are coefficients expressing the vitality state of healthy, damaged, severely damaged and dying trees, %.

At $L$ equal to 100-80% the vitality state of the stand is assessed as healthy, at 79-50% stands are considered damaged (weakened), at 49-20% – severely damaged (severely weakened), at 19 and lower – completely wrecked. In addition, we identified in the stands a number of damages affecting the vital state of trees to a certain extent: those are deadwood, frost cracks and dieback.
3. Results and discussion
In the sample plots (SPs) there was carried out a complete count of trees, with the following their division into different categories, according to their thickness stages and state. As a result of the surveys carried out, 8500 trees were counted.

The sample areas for the observation of plantations in parks and miniparks in the city were selected, considering the coverage of the sanitary protection zones of industrial enterprises and their uniform distribution within the urban area as regards the level of pollution (table 2). As far as possible, we tried to select large plantings that were able to form a stable phytocenosis.

In urban conditions, the most weakened species turned out to be balsam poplar trees, resistant to pollution and growing in the immediate vicinity to the aluminum plant, SP 36 and 37. Meanwhile, in other districts of the city poplar trees have higher vitality index values. As for tree species less resistant to pollution in the trial areas, their vitality state is becoming to be influenced by other factors, for example, improper plant care.

| Number of sample plot | Level of pollution | Species of plantations                                                                 | Number of studied trees | Vitality state of the stand according to V.A. Alekseev index, % | state |
|-----------------------|-------------------|----------------------------------------------------------------------------------------|-------------------------|---------------------------------------------------------------|-------|
|                       |                   | *parks, miniparks*                                                                      |                         |                                                              |       |
| 8                     | average           | Balsam poplar, Box elder, Scots pine, Chinese elm, European white elm, Small-leaved lime, Siberian crabapple, Ussurian pear, Silver birch, Siberian larch, European spruce, Blue spruce, Siberian fir, Common ash, Bird cherry | 361                     | 64.1                                                          | Weakened |
| 10                    | weak              | Scots pine, Balsam poplar, Silver birch                                                 | 106                     | 64.0                                                          | Weakened |
| 19                    | moderate          | Balsam poplar, Box elder, Chinese elm, Bird cherry                                      | 251                     | 56.9*                                                         | Weakened |
| 31                    | weak              | European white elm, Chinese elm, Balsam poplar, Small-leaved lime, Box elder, European spruce, Siberian larch | 332                     | 75.9*                                                         | Weakened |
| 36                    | strong            | Balsam poplar, Chinese elm, Manchurian cherry                                           | 51                      | 47.7                                                          | Severely weakened |
| 37                    | strong            | Balsam poplar                                                                          | 90                      | 46.8                                                          | Severely weakened |
| 45                    | weak              | Silver birch, Siberian crabapple, Chinese elm, Box elder                                | 463                     | 72                                                            | Weakened |
| 61                    | moderate          | Silver poplar, Black poplar, Balsam poplar, Scots pine, Siberian larch, Siberian spruce, Chinese elm, Box elder, Silver birch, Goat willow, Siberian crab apple | 222                     | 73.5                                                          | Weakened |
| 62                    | moderate          | Siberian crab apple                                                                     | 532                     | 40                                                            | Severely weakened |
| 63                    | moderate          | Siberian crab apple                                                                     | 621                     | 38                                                            | Severely weakened |
| 64                    | moderate          | Balsam poplar                                                                           | 410                     | 43                                                            | Severely weakened |
| 65                    | moderate          | Silver birch, Balsam poplar                                                            | 210                     | 66                                                            | Weakened |
| 66                    | moderate          | Chinese elm, Balsam poplar                                                             | 291                     | 60                                                            | Weakened |
|                       |                   | *urban forests*                                                                          |                         |                                                              |       |
| 1                     | weak              | Scots pine, Silver birch                                                               | 343                     | 54.0                                                          | Weakened |
| 67                    | weak              | Silver birch                                                                            | 42                      | 45.5                                                          | Severely weakened |
In addition to urban plantations which are heavily affected by air pollution, the significant stress is felt by urban forests which are a source of clean air in urban areas and one of the most often visited and favorite recreational areas of city dwellers.

Sample areas in urban forests were also chosen among overmature birch forests and Scots pine plantations dated to the 1940s. Scots pine plantations are represented by mixed grass, mixed grass – reed grass and green-moss sedge – mixed grass forest types. The birch forests belong to sedge – mixed grass forest types. Under the canopy of the plantations there is a well-developed undergrowth including rose hips, bird cherry, rowan, apple, acacia, currant, pea shrub, honeysuckle, raspberry, cherry, viburnum, willow, cotoneaster, and hawthorn. Also, there were found young pine, birch, cedar, fir and aspen trees.

The number of birches without signs of weakening and weakened birches totals 37%, severely weakened – 47%, withered and dead – 16%. Among Scots pines the situation is similar: the number of trees without signs of weakening and weakened trees comprises 42%, severely weakened – 44%, withered and dead – 14%. Ongoing weakening does not exceed 10%. Severely weakened trees are in unstable condition, and under unfavorable circumstances they may become strap in the coming years. While this can be stated with certainty for the overmature birch forest, in the pine forest, if care is taken, severely weakened trees can live for many years.

Parks and public gardens in the city were also scrutinized for species diversity. The survey revealed that there are 38 species of trees and shrubs belonging to 28 genera and 13 families. Since not all green objects of the city have been surveyed, this list is to be supplemented further.

The most common are representatives of 10 species and 9 genera of the family Rosaceae, Pinaceae – with 4 genera 6 species, and Salicaceae – with 2 genera and 6 species. The research has demonstrated that 16 species of the local (aboriginal) flora are used in landscaping of parks and public gardens in Krasnoyarsk, 6 species of which belong to coniferous trees of Pinaceae family and 10 species to deciduous trees. Plantations in parks and miniparks of the city can boast species of invasive trees. The most widespread are species from flora of North America – balsam poplar and box elder, as well as a species from the Far East – Chinese elm.

The dominant species in the surveyed plantations of Krasnoyarsk are representatives of the willow family (Salicaceae) – balsam poplar (Populus balsamifera L.), maples (Aceraceae) – box elder (Acer negundo L.), elms (Ulmaceae) – Chinese elm (Ulmus spinato-ramosa Dieck.), and Rosaceae – Siberian crab apple (Malus baccata (L.) Borkh) (figure 2).
Among coniferous woody plants, the predominant species in parks and public gardens in the city is Siberian larch, followed by Siberian spruce in terms of the number of trunks, and a still smaller proportion is held by Scots pine.

If we turn to the principal objectives of creating green spaces, besides facilitating the area and introducing architectural and artistic design, the main tasks of it include protection of the area from adverse weather and climatic factors, as well as protection from transport and other kinds of anthropogenic pollution. In that case, when selecting tree species to create noise, emissions and dust protective plantings, it is necessary to take into consideration their resistance to the action of atmospheric pollutants. According to the guidelines for roadside landscaping, [13] the most resistant species are:

- conifers: Siberian larch;
- deciduous species: ash, linden, poplar;
- bushes: Siberian pea shrub, spirea, honeysuckle, rose hip.

According to other literature data [14-16], plants are divided into three categories according to the degree of gas resistance:

- **resistant** (Blue spruce, junipers, balsam and Canadian poplar, white and black poplar, common ash, apple tree, different types of maple, linden, elm, Siberian pea shrub)
- **relatively resistant** (downy and silver birch, horse chestnut, small-leaved lime, rowan ash, common lilac)
- **low-resistant** (Siberian fir, barberry, Scots pine).

The data presented are tentative, as they have been obtained by different researchers from laboratory experiments. However, this information can be useful in selecting a range that can be sustainable in urban areas, performing an environmental protection function and having an aesthetic value at the same time.

### 4. Conclusion

The research conducted has shown that the range of woody plants growing in parks and miniparks of the city is quite wide, however, it should be noted that the city has a small range of shrub plants.

The sanitary and hygienic role of plants is the most important factor for creating favorable conditions for human life and activities in the urban environment. That is why rating of plantations
according to the vitality state of different species growing in different city conditions with varying levels of pollution is useful for developing clear criteria for the expedience of certain species of woody plants in the conditions of Siberian industrial centers.

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