Greening of the administrative-territorial structures in the urban space

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Abstract. Vegetation is an important means of city landscape since it provides for long-term protection of environmental urban sustainability. The paper deals with urban influence on the state, resistance and structure of parkland in Voronezh city (Russia) and describes a planning structure developed for sustainable vegetation under high anthropogenic load. Studied parklands located in different city districts have specific natural features, history of formation, structure, application and area. By means of the integrated approach to planning, monitoring and design of green space we have evaluated spatial structure type, sanitary and aesthetic state as well as plants condition, stability class, degradation degree and recreational load on plants. The results have revealed unorganized mass visiting of parks which causes deterioration and destruction of plants. Accordingly there arises a need to create a long-living parkland which would be resistant to adverse conditions caused by proximity of roads and mass visitation. The supply of plants for public objects, the state and resistance of plants to urban factors are indicators of sustainable parkland.

1. Introduction

The protection of the urban environment becomes an issue with a rapid growth of the city population. The United Nations forecasts the growth of urban population from 54% up to 66% by 2050 [1]. Meanwhile, urban improvement is an important task for the formation of healthy and comfortable urban environment [2].

The improvement of ecological situation in cities is associated with the improvement of the greening system which is seen as an interconnected and balanced distribution of green territories – or green space – in cities, determined by the architectural and planning organization of the city and the development plan which provides for the coherence with the suburban vegetation [2].

Greening of urban space has become a major topic to concern because the vegetation forms the image and aesthetics of the city and assures emotional comfort of the city dwellers. Today many cities use the advanced gardening methods as roof gardens or vertical gardens in Milan, Italy [3] or contraction of green areas in Ho Chi Minh, Vietnam) [4]. In Nairobi the urban vegetation turned into a solid waste landfill, and the urban population growth puts pressure on the green areas resulting from overuse and misappropriation [5]. The German experience shows that green infrastructure requires an
integrated approach and combined knowledge and efforts of engineers, architects, ecologists, economists, managers and politicians [3]. The solution to these problems will make it possible to create a natural framework in the city space.

Green infrastructure concept in Russian cities includes the formation of the environmental infrastructure [6]. In many cities, including Voronezh, one of the biggest industrial and cultural centers of the Central Black Soil region of Russia, the greening system is intrinsically linked to the key factors of landscaping and the historical planning structure of the city. Greening of the city improves the urban environment and significantly limits anthropogenic pressure on the city [7].

There are many ecosystem-related functions of the parkland: air clearing from dust and deleterious gases, creation of the comfortable microclimate, bactericidal effect, noise protection, creation of habitat of other organisms, formation of urban soil and protection from soil erosion, snow and rainwater trapping, disintoxication [8]. The main indicators of city greening are the supply of green areas of common use, live plants and their resistance to urban factors [9].

The purpose of this study is an in-depth investigation of urban influence on the state, sustainability and spatial structure of parkland in Voronezh.

2. Experimental part

Six sites located in different administrative districts of Voronezh city (figure 1) were chosen for the study. All sites have different environmental conditions and different purpose and areas (table 1).

| Site name                          | Function     | Area, ha | Location                  |
|------------------------------------|--------------|----------|---------------------------|
| Alye Parusa (The Scarlet Sails)    | Play park    | 12.0     | Levoberezhniy Midpart     |
| Delfin (The Dolphin)               | Play park    | 5.0      | Zheleznodorozhniy Midpart |
| Orlyonok (The Eaglet)              | Play park    | 6.2      | Tsentralniy Center        |
| Tanais                             | Play park    | 24.0     | Sovetskiy Periphery       |
| Durov                              | Public garden| 3.0      | Leninskiy Center          |
| Pobedy (The Victory Park)          | Public garden| 9.0      | Kominternovskiy Midpart   |

The green space of common use have a high rank in the organization of the Tsentralniy district where there are 36 green sites on a relatively small (6,380 ha) built-up territory. The Levoberezhniy district is the leader among all city districts by the number of the green space of common use: it has 7 parks, 27 public gardens (squares) and 13 boulevards on its territory of 12,400 ha. A problematic situation is observed in the Zheleznodorozhniy, Kominternovskiy, Leninskiy and Sovetskiy districts, having the only one park, 24.5 and 4.2 ha; this explains the mass attraction of residents of these districts to the suburban forests (table 2).

A landscape-environmental investigation of the studied sites was performed including determination of plants resistance and condition, evaluation of aesthetics, degradation degree, and recreational load [10]. Many studies state that plants, relief, water resources and buildings altogether form the parkland space [11-13].

Assessment of plants condition included the general condition of the area, state of vegetation and soil, and visitor load according to the stability scale (table 3). Stability of plants showed their overall state, quality of growth and development [14].
The state of plants was scored on a three-point scale [15]:

1. Good: healthy wood plants with the developed crown and branches, without visible damage, and with normal leafing; grass carpet (grain-type) with a dense closed stand without "bald spots", regularly mowed, absent of broadleaf weeds; flower garden: compact grouping of healthy plants with clear contours, absent of wilted or wither plants.

The study also took into account the age of plants, the degree of suppression, and the impact of the adverse environmental factors. The state of vegetation, the stability and aesthetic state of wood plants were assessed visually on the basis of the external state rating scale [14]. The purpose of the assessment of vegetation in parks was to determine the general condition of trees, bushes, grass and flowers.

2. Moderate: wood plants look healthy, but have crown development defects and visible damage which however does not threaten their life; a slightly curved stem, with dry shoots on branches (up to 10 - 15%); bushes with coppice; grass carpet (grain-type) with loose spots (up to 40%) with presence (up to 15%) of undesirable broadleaf plants; flower garden in disorder, presence of wither plants (up to 40%), with unclear contours.

3. Poor: wood plants do not meet their functional use, having a deformed crown, with presence of dry shoots and branches, weakly colored small leaves, curved stem, signs of mycosis and pest contamination which threaten the plants life; bushes with coppice, dry shoots, small leaves, and having suppressed appearance in general; grass carpet is heavily degraded, has a large number of broadleaf plants, 80% of cover is absent, massively trodden; flower garden without contours or badly contoured, with presence of wilted plants.

Aesthetic evaluation of the landscape was performed by visual comparison by experts and defined by the following parameters [9]:

1. The state of vegetation, the ratio of plane and volume elements, water surface, and architecture – these are the most important factors - 30 scores;
2. Scenery spots - deepness, uniqueness and prospect depth - 10 scores;
3. Relief and geoplastics - direction of slopes, % - 5 scores;
4. Soil and plants - 5 scores.
Table 2. Distribution of the green space within the administrative districts.

| #  | Administrative district | Area, ha | Green area |
|----|-------------------------|----------|------------|
|    |                         |          | City total: 59,269 | 590.3 | 8.4 |
| 1  | Levoberezhniy           | 12,400   | 112.4      | 0.9   |
|    | parks                   |          | 45.9       | 0.4   |
|    | squares                 |          | 30.3       | 0.2   |
|    | boulevards              |          | 36.2       | 0.3   |
| 2  | Zheleznodorozhniy       | 18,317   | 34.9       | 0.2   |
|    | parks                   |          | 5.0        | 0.02  |
|    | squares                 |          | 16.2       | 0.08  |
|    | boulevards              |          | 6.0        | 0.03  |
|    | embankment              |          | 7.7        | 0.04  |
| 3  | Leninskiy               | 1,872    | 27.2       | 1.5   |
|    | parks                   |          | 4.2        | 0.3   |
|    | squares                 |          | 10.9       | 0.6   |
|    | boulevards              |          | 9.2        | 0.4   |
|    | embankment              |          | 2.9        | 0.2   |
| 4  | Kominternovskiy         | 4,700    | 80.1       | 1.7   |
|    | parks                   |          | 22.8       | 0.5   |
|    | squares                 |          | 19.4       | 0.4   |
|    | boulevards              |          | 31.1       | 0.6   |
|    | alleys                  |          | 6.8        | 0.2   |
| 5  | Sovetskiy              | 15,600   | 165.4      | 1.1   |
|    | parks                   |          | 24.0       | 0.16  |
|    | squares                 |          | 22.6       | 0.13  |
|    | boulevards              |          | 19.8       | 0.12  |
|    | forest park             |          | 99.0       | 0.7   |
| 6  | Tsentralniy             | 6,380    | 170.3      | 2.7   |
|    | parks                   |          | 125.06     | 1.9   |
|    | squares                 |          | 25.52      | 0.5   |
|    | boulevards              |          | 13.0       | 0.2   |
|    | forest park             |          | 6.7        | 0.11  |

Determination of the ecological and recreational capacity of the objects involved determination of their degradation stage. At the 1st stage of degradation almost no trace of visiting of phytocoenosis by people can be found. At the very last, the 5th stage of degradation, as a result of high recreational loads the forest floor, herbage and understory disappear, the herbage leans to the trunks of trees which stand on a grassless, firm soil [14].

Stability classes of natural complexes and their resistance to recreational loads were determined depending on the type of forest conditions and dominating species according to the 5-score scale (where the 1st class describes the most stable plants). Then, the maximum permissible recreational load per 1 ha was found, which is typical of the determined degradation stages, stability class and
dominating species. And finally the actual load and ecological recreational capacity were determined [14].

### Table 3. Plant stability scale [14].

| Stability class | Characteristics, main causes and symptoms |
|-----------------|-------------------------------------------|
| Class 1         | Healthy vegetation with signs of good growth and development; min 90% of healthy trees, the loose soil, max 5 people per 1 ha of visitor load. |
| Class 2         | Vegetation similar to Class 1, but the share of healthy trees ranges from 71% to 90%, poorly compacted soil, average visitor load of 6 to 15 people per 1 ha. |
| Class 3         | Vegetation has some signs of slowing growth and development of some trees, the share of healthy trees is 51% to 70%. |
| Class 4         | Vegetation has visible signs of slowing growth and development. The share of healthy trees is 25% to 50%. In many cases the forest stand do not meet the site conditions, has low index and poor quality. There are less than 25% of healthy trees. The state of vegetation poses a threat to the neighboring forest stands because in most cases this class vegetation is a locus of growth of injurious organisms and diseases. As such it should be urgently cut. |
| Class 5         | |

3. Results and discussion

Allocation of the green space of common use in the general structure of the green zones of Voronezh is primarily due to the fact that they play a very important role in the planning of urban territory. Table 3 shows the supply of the green space of common use in Voronezh.

The green space of common use have a high rank in the organization of the Tsentralniy district where there are 36 green sites on a relatively small (6,380 ha) built-up territory. The Levoberezhniy district is the leader among all city districts by the number of the green space of common use: it has 7 parks, 27 public gardens and 13 boulevards on its territory of 12,400 ha. A problematic situation is observed in the Zheleznodorozhniy, Kominternovskiy, Leninskiy and Sovetskiy districts, each having just one park, 24.5 and 4.2 ha; this explains the mass attraction of residents of these districts to the suburban forests.

According to the planning regulations of the Russian Federation [14] the availability of the green space of common use in major, large and big cities must be 16 m$^2$ per 1 person. This norm could be increased for forest-steppe and steppe territories by 10...20%, which corresponds to the regulatory availability of 19.2 m$^2$/person (table 4).

### Table 4. Supply of the green space of common use in Voronezh.

| Site name                  | City districts | Total |
|----------------------------|----------------|-------|
| Parks and gardens, ha      | 53.0 3.5 6.0 2.9 37.8 138.6 | 241.8 |
| Squares, ha                | 14.9 14.5 11.4 17.5 14.2 32.8 | 105.3 |
| Boulevards, ha             | 20.9 19.2 16.2 24.6 19.2 15.3 | 115.4 |
| Total of green space of common use, ha | 88.8 37.2 33.6 45.0 71.2 186.7 | 462.5 |
| Population, thousand people| 182.7 98.1 123.3 242.4 170.4 91 | 908.9 |
| Supply of green space of common use, m$^2$/person | 4.9 3.7 2.7 1.9 4.2 20.5 | 5.1 |
Therefore, the regulatory availability of the green space of common use in Voronezh must be over 20 m²/pers. The indices comparison shows that the availability of the green space in Voronezh is by 6.7 m² lower than the bottom limit of the recommended norm.

The main reasons of the poor state of vegetation, being the basic element of the greening system, are:

1. Violation of insolation regime.
2. Improper pruning of trees.
3. Predominance of homogeneous row planting.
4. Inaccurate selection of species of trees and bushes.

Having considered the ratio of plant species present on the studied sites it may be noted that the following species - small-leaved linden (Tiliacordata), Norway maple (Acerplatanoides), Siberian elm (Ulmuspumila) are used in parts of all sites, but the maximal area of the studied sites is occupied with the Scotch pine (Pinussylvestris) on 118,689 m². This phenomenon is due to the fact that the parks (Alye Parusa, Delfin, Tanais) were created on the woodlands/forests, where the Scotch pine is the predominant species (figure 2).

The state of park planting is shown in table 5. The description of test sites included the plant biometrics, the type park planting (alley, line, group, solitaire). The location of test sites was recorded on the park plans.

**Table 5. State of trees and bushes.**

| Site               | Good Wood plants | Grass carpet | Flower garden | Moderate Wood plants | Grass carpet | Flower garden | Poor Wood plants | Grass carpet | Flower garden |
|--------------------|------------------|--------------|--------------|----------------------|--------------|--------------|------------------|--------------|--------------|
| Alye Parusa Park   | 80               | 80           | 80           | 19                   | 10           | -            | 1                | 10           | -            |
| Delfin Park        | 20               | -            | -            | 60                   | 20           | -            | 20               | 80           | -            |
| Durov Park         | 60               | 60           | -            | 40                   | 40           | -            | -                | -            | -            |
| Orlyonok Park      | 25               | 10           | -            | 60                   | 75           | 35           | 15               | 15           | 65           |
| Tanais Park        | 80               | -            | -            | 10                   | -            | -            | 10               | -            | -            |
| Pobody Park        | 95               | 80           | 80           | 5                    | 20           | 20           | -                | 30           | -            |
Table 6. Ratio of vegetation planting in Voronezh by stability classes.

| Site Name         | Stability class,% |
|-------------------|-------------------|
|                   | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 |
| Alye Parusa Park  | 7       | 13      | 52      | 24      | 4       |
| Delfin Park       | 5       | 20      | 70      | 5       | -       |
| Orlyonok Park     | 5       | 10      | 60      | 20      | 5       |
| Tanais Park       | 17      | 24      | 38      | 13      | 8       |
| Durov Park        | 7       | 16      | 38      | 32      | 7       |
| Pobedy Park       | 8       | 28      | 35      | 24      | 5       |

Table 7. Recommended measures to advance the stability class of the parkland.

| Stability Class | Recommended Measure                                                                 |
|-----------------|---------------------------------------------------------------------------------------|
| 1               | Measures related to the day-to-day care (watering, cultivation and mulching of soil, fertilizing if necessary). |
| 2               | To improve a green space to the stability class 1 there is a need for carrying out sanitation and regenerative pruning and implementation of measures recommended for stability class 1. |
| 3               | Immediate sanitation cutting. Implementation of measures related to conservation and protection of vegetation, soil management, control of visitor load. Removal of mechanical damage, namely, the existing cuts and hollows should be sealed with appropriate mixtures and solutions. |
| 4               | Conversion cutting which provides for the recovery of more valuable and stable stands. |
| 5               | Immediate sanitation clear cutting. Development of measures to restore the park site in accordance with its zonal purpose. |

The unorganized mass visiting of parks causes destruction of the plants. That is why the following main tasks must be solved:

1) implementation of measures to ensure the formation of a long-living (aesthetically) beautiful park landscape, which would be resistant to the adverse environmental conditions stemming from the proximity of roads and mass visitation.

2) creation of favorable conditions for mass leisure in parks.

Table 8. Aesthetic evaluation of the studied sites.

| Site            | Alye Parusa Park | Delfin Park | Orlyonok Park | Tanais Park | Durov Park | Pobedy Park |
|-----------------|------------------|-------------|---------------|-------------|------------|-------------|
| Aesthetic       | 47               | 28          | 38            | 34          | 38         | 46          |
| evaluation, scores |

In order to solve the first task the stability of plants has been determined by the following criteria - their general form and quality of growth and signs of drying of trees: top-drying, crown thinness, yellowing of needles and leaves and other signs.

The largest share of plants on the studied sites have the stability classes 2 and 3 (Table 6). Healthy trees comprise 71% to 90%, the average visitor load is 6 to 15 per 1 ha, vegetation with clear signs of slowing growth and development of the part of trees range from 51% to 70%. Some relevant measures were designed to improve the stability class of the parkland (table 7).

The most popular recommended measures include sanitary and renovation pruning, repairs of the mechanical damage of plants, measures of plant protection and soil management.
The territories of the studied sites belong to the semi-open type of spatial structure and have Class 2 by the sanitary-hygienic assessment. Aesthetic evaluation data are presented in Table 8. The results shown in Table 8 indicate that the most leisure-friendly parks are Alye Parusa and Park Pobedy. Other parks require implementation of measures that would improve their state according to the aesthetic scoring.

Table 9 shows the data for finding recreational capacity and load of the studied sites.

| Site, ha | Vegetation content | Stability class | Predominant species | Digression stage | Load / ha | On site |
|----------|--------------------|-----------------|---------------------|------------------|----------|---------|
| Alye Parusa Park, 12.0 | B2 3 Scotch pine | 2 | 7.5 | 1.8 | 90.0 | 21.6 |
| Delfin Park, 5.0 | B2 4 Scotch pine | 3 | 4.4 | 2.9 | 22.0 | 14.5 |
| Durov Park, 3.0 | B2 3 aspen | 2 | 7.5 | 1.8 | 22.5 | 5.4 |
| Orlyonok Park, 6.2 | B2 3 Acer (maple) | 2 | 7.5 | 1.8 | 46.5 | 11.16 |
| Tanais Park, 24.0 | B2 3 Scotch pine | 3 | 7.5 | 2.5 | 180.0 | 60.0-180.0 |
| Pobedy, 9.0 | B2 3 birch, aspen | 2 | 7.5 | 1.8 | 67.5 | 16.2 |

From the data in Table 9 it is concluded that the actual load in Alye Parusa, Orlyonok, Pobedy and Durov parks does not exceed the ecological recreational capacity, and these results evidence the high potential of use of these sites for leisure. The same data for parks Delfin and Tanais is close to ecological capacity limits, and thus evidence a significant recreational potential of these sites with a need of a close management of their recreational use.

4. Conclusion
The presented analysis of the existing state of vegetation on the studied sites evidences the need to expand the range of green species in parks and implement measures related to improvement of their resistance.

The greening rate, the supply of green space of common use, and the state and resistance of plants in the urban environment are all indicators of the sustainable development of urbanization centers.

The ecological recreational capacity of the absolute majority of the studied sites is above the actual load and suggests a significant recreational potential of parks in Voronezh. Therefore, proper maintenance of live plants, protection measures and expansion of the green areas will help improve the leisure quality for the city dwellers and upgrade the aesthetic and decorative quality of the parkland.

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