Voronezh parkland landscaping concept

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Abstract. The relevance of the study is explained by the deterioration of plants in the parkland of Voronezh. The important issue is the assessment of urban plants and the impact of the anthropogenic factors of urban environment. The purpose of the study is to analyze the state of the existing plants and the park state, and to recommend measures to improve the structure of the park by updating the planning decisions, introducing the additional assortment of plants and changing the type of spatial structure of plants, as a sustainable part of the green infrastructure of Voronezh. The assessment of the current state of the plants has revealed a systematically decreasing share of the public green space and the reduction of the relative plant life under anthropogenic loads. The dead trees accounting for 35 % must be removed. The expansion of the assortment of plants and updating the planning decisions will form a positive trend in the reconstruction of public parks. Changing the city spaces will create the favorable conditions and environment-forming functions of green plants, and make for the comfortable life of people of Voronezh.

1. Introduction

Under the higher anthropogenic loads and in the uncomfortable conditions of life in cities due to the air pollution by the emissions of vehicles and industries, the landscaping and greening of communities has the particular importance. The landscaping objects (gardens, parks, squares) are distressed in many cities of the world. City improvement is one of the important tasks of creating a comfortable urban environment [1].

Currently a stressful environmental situation has developed in Russian cities, the improvement of which is directly related to the improvement of the greening system, which refers to the scientifically-based spatial distribution of all the components of the urban greening in accordance with the urban planning zones, soil-related, climatic and other factors, to achieve an optimal ecological, hygienic and aesthetic effects [2].

The “green infrastructure” notion is used in the international practice of urban planning. It focuses on the ecological value of the territory, considers the full range of landscape changes and serves as the basis for the formation and development of the General Plan [3]. Green infrastructure in the United States includes the preserved natural plant communities in the cities and artificial green spaces. The development of green infrastructure is aimed at preserving bio-diversity, climate and water regulation, water treatment, preserving and restoring the natural landscapes, creating conditions for recreation near residences, reducing the area of sealed soil; environmental education of population. The “green infrastructure” in the European Union includes natural and fragmented ecosystems with a high level of bio-diversity, hedges (eco-corridors), re-cultivated sites, eco-bridges and eco-bridges, multifunctional.
zones on the city borders, parks and squares, green walls and roofs, ‘ecotone’ areas on the border of urbanized and suburbanized areas [4].

The main function of the green infrastructure is to minimize the impact of anthropogenic factors and to increase the impact of the natural potential of the city [5].

The relevance of this study is explained by the deterioration of the plants in the public green sites of Voronezh. In this regard, the city administration pays great attention to the issues of modernization and improvement of the urban environment [6], including a solution of the problems related to the current state and future development of the city parks. Therefore, the study of the urban vegetation and the impact of urban anthropogenic factors is of the prime importance today. The pollution level, the functional planning structure and the characteristics of green species used in the urban vegetation are taken into account when forming the sustainable green spaces in the urban environment.

2. Materials and methods
The question of current importance is the creation of a sustainable system of green plants as the basis of the green infrastructure of the parks in Voronezh.

The object of the study is the territory of the Dolphin Park located in the Zhelezodorozhny district of Voronezh (figure 1). The total area of the park is 5.0 ha.

The Dolphin Park is one of the public recreation sites of the city located on the bank of the Voronezh water storage reservoir (Voronezhskoe Vodokhranilische). The park territory lies from the reservoir shores in the south-west and west to the North Bridge (Severny Most) in the north. Such a unique location makes it highly comfortable for the leisure of the citizens.

Figure 1. Plan of the Dolphin Park.
Figure 1 shows the plan of the Dolphin Park dated year 2000, with the symbols indicating the locations of trees and shrubs, flower decorations, architectural structures, paths and playgrounds, attractions and water bodies. The park is located in the lowland of the left bank of Voronezh. It is characterized by a flat relief with a uniform grade. The picturesqueness of the park is achieved by the views to the water reservoir of Voronezh.

The Scots pine (Pinus sylvestris) is the prevailing type of trees and shrubs in the park. There are deciduous species in the undergrowth: mountain ash (Sorbus aucuparia), ash-leaved maple (Acer negundo) and small-leaved elm (Ulmus pumila). The existing assortment is shown in figure 2.

A list of existing plants in the Dolphin Park: 1 – Scots pine (Pinus sylvestris); 2 – Balsam poplar (Populus balsamifera); 3 – White willow (Salix alba); 4 – Common birch (Betula pendula); 5 – Small-leaved elm (Ulmus pumila); 6 – Ash-leaved maple (Acer negundo); 7 – Sorbus intermedia; 8 – Black alder (Alnus glutinosa); 9 – Indigo-bush amorph (Amorpha fruticosa); 10 – Common catalpa (Catalpa bignonioides); 11 – Blue spruce (Picea pungens); 12 – Bird cherry (Prunus padus); 13 – Wild apple (Malus silvestris); 14 – Vanhoutte spiraea; 15 – Pacific ninebark (Physocarpus capitatus); 16 – False acacia (Robinia pseudoacacia); 17 – Cotoneaster brilliant (Cotoneaster lucidus); 18 – Common lilac (Syringa vulgaris); 19 – Pyramidal poplar (Populus pyramidalis).

The plants growing at the shore include pyramidal poplar (Populus pyramidalis), white poplar (Populus alba), grey alder (Alnus incana), chokecherry (Prunus virginiana), small-leaved elm (Ulmus pumila), common birch (Betula pendula), Norway maple, ash-leaved maple, English dogwood (Philadelphus Coronarius), common lilac (Syringa vulgaris).

The assessment of the existing plants has revealed that, in general, they occupy 68.4 % of the park territory. The plants have the forms of hedges, alleys, solitaires, simple and complex groups, horizontal canopy single-storied massifs. 35 % account for the dead trees. Some areas have chaotic shrubbery. The assortment does not have much variety.

Considering that the park has a picturesque location in the city, we have proposed some changes to the planning structure and recommended the additional assortment of plants taking into account the biological and environmental characteristics.

A landscape-ecological analysis of the park was carried out in order to make an updated architectural and planning decision for the park area. The analysis included the determination of the
spatial type, state of plants, stability class and degradation degree. On the basis of the study, a functioning zoning was developed, and it was proposed to introduce the additional assortment of the plants [7].

The method of determination of the spatial structure types is described below:

- **Closed spatial structure.** It is represented by the plants with no or limited visuality which create psycho-physiological conditions due to isolation and overhead canopy. The canopy density is 0.6 - 1.0. Horizontal closure (single-storeyed) and vertical closure (multi-storeyed) are possible.
- **Semi-open spatial structure.** The canopy density is 0.5-0.2. It is divided into areas with grouped or uniform distribution of trees.
- **Open spatial structure.** It is represented by all areas which are not occupied by the dense plants and structures (Razumovsky Y. V.) [8].

The study included the visual assessment of the state of existing plants by their bio-morphological characteristics: the crown density, leafage or needle packing, the correspondence of the size and color of the leaves and needles and the growth of shoots to the norms (by specie and by age), the presence/absence of deviations in the textures of the trunk, crown, branches and shoots, top-drying or the presence and share of dry branches in the crown, the integrity and condition of the bark and phloem [7]. In addition to the tree stands, the state of shrubs, grass and flowers (Table 1) was assessed.

### Table 1. Assessment scale of the state of shrubs and grassland (by N N Gusev and V A Agaltsova).

| Shrubs                                      | Grassland                                      | Degradation degree |
|---------------------------------------------|-----------------------------------------------|--------------------|
| Shrubs are healthy, aged up to 30 years, non-revived, with no or very few dry branches | The grass canopy is intact; it includes typical species. | 1                  |
| Revived shrubs are in a good state, with no or very few dry branches | Grass canopy has loose spots (up to 5 %) and weeds or non-typical species (5-10 %) | 2                  |
| Shrubs over 30 years old of the II and III generation are in a good state, without dry branches | Grass canopy is downtrodden by 6-10 %, has weeds or non-typical species up to 11-20 %. Soil is compact. | 3                  |
| Fragmented shrubs with old roots and lots of dry branches | Grass canopy is poor, downtrodden by 41-60 %, weed and non-typical species occupy 21-50 %. The soil is very compacted, there is some construction-related and other waste | 4                  |
| Completely fragmented shrubs (with only some weak growth visible at the old roots) | Grass canopy is downtrodden by 61-100 % or represented by weeds and non-typical species. The soil is heavily compacted, there is a lot of construction-related and other waste | 5                  |

The stability assessment of the plants was done using the 5-class scale by V. P. Kovtunov (1977). The plants stability assessment shows their general state and growth quality (Table 2).

The use of abandoned parks by the residents is not regulated, which has a significant impact on some of the most visited parks [8].

Ecosystems of parks under the recreational loads degrade to the complete destruction. Recreational load is uneven and it grows, for instance, on paths and in accidental recreation areas, but is mostly absent in areas with canopy density of 0.8 to 1.0. The scale of recreational digression of the forest (Table 3) helps reveal the degraded areas of the park. The study shows that the major part of the park has reached the third degree of digression, which is considered as a permissible load and might be regulated in order to restore these areas.
Table 2. Plant stability scale (Kovtunov, 1977).

| Stability Class | Characteristics, main causes and symptoms |
|-----------------|-------------------------------------------|
| Class 1         | Healthy plants with signs of good growth; min 90% of healthy trees, the loose soil, max 5 people per 1 ha of visitor load. |
| Class 2         | Plants are 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         | There are some signs of slowing growth of trees. The share of healthy trees is 51% to 70%. |
| Class 4         | There are clear signs of slowing growth. The share of healthy trees is 25% to 50%. In many cases, the stand does not meet the site conditions, has low index and poor quality. |
| Class 5         | There are less than 25% of healthy trees. The state of plants poses a threat to the neighboring stands because, in the most cases, this is a locus of growth of injurious organisms and diseases. As such, it should be urgently cut. |

Table 3. Assessment scale of the recreational digression of the forest environment.

| Characteristics of the site | Digression degree |
|-----------------------------|-------------------|
| No signs of disturbance of the forest environment, normal growth of trees and shrubs, no mechanical damages; uneven-aged undergrowth is viable. Moss and grass canopy includes typical species for this type of forest; (springy) ground litter is intact. Recreational regulation is not required. | 1 |
| Minor changes in the forest environment and a weaker growth of trees and shrubs, a few mechanical damages; uneven-aged undergrowth is viable, of medium thickness, has up to 20% of damaged and shrunk specimens. The projective cover of moss is up to 20%, of grass canopy is up to 50% (of which 1/10 is the meadow grass); small deterioration of the litter, the soil and litter are slightly compact; a few bare roots of trees are visible, about 5% of the area is downtrodden to the mineral layer of the soil. Some recreational regulation is required. | 2 |
| Significant changes in the forest environment, growth of trees is weak, up to 10% of trunks have mechanical damage; even-aged undergrowth is depressed, of medium or rare thickness, 21-50% of damaged and shrunk specimens. Moss on the tree trunks, their projective cover is 5-10%, of the grass canopy is 70-60% (of which 2/10 is the meadow grass), weeds are visible; the litter and soil are considerably compacted, a lot of bare roots of trees are visible, 6-40% of the area is downtrodden to the mineral layer of the soil. Significant recreational regulation is required. | 3 |
| The forest environment is severely disrupted, with block-and-meadow type of stands, the trees are highly depressed, 11-20% of trunks have mechanical damage; undergrowth is non-viable (mostly in blocks), rare or absent, more than 50% of damaged and shrunk specimens are visible. Moss is absent, the projective grass cover is 59-40% (of which 1/2 is the meadow grass and weeds). There are a lot of bare roots of trees, there is no litter in open places, about 41-60% of the area is downtrodden to the mineral layer of the soil. Strong recreation is required. | 4 |
| The forest environment is degraded; tree stand is sparse, of block-and-meadow type, the trees are very weak or dry, more than 20% of the trees have mechanical damage; the undergrowth, moss and litter are absent, the projective grass cover is up to 10% (3/4 of meadow grass and weeds), the roots of the majority of the trees are bare, more than 60% of the area is downtrodden to the mineral layer of the soil. No recreation is possible. | 5 |
The measures aimed to improve and increase the recreational capacity and sustainability of the parkland (update of planning decisions, introduction of the additional assortment, arrangement and maintenance of the proper sanitary conditions of the territory) allow for stabilization of the park ecosystems under the increasing anthropogenic load.

The green infrastructure of Voronezh has developed for over a century, and this development is continuing presently. The most significant stages of the development took place at the beginning (1900–1915) and in the middle of the past century (1950–1970), when parks, squares, boulevards, gardens, arboretums and plant nurseries were created intentionally and rapidly. In the recent years, the municipal authorities and citizens have become more interested in the problems of urban greening. Monitoring of the state of the plants reflects the positive trends in the development of the green infrastructure [9]. A greening system has been created and is being developed in the city, the funding has increased, and new green areas have appeared.

3. Results and discussion
Table 4 presents the results of the assessment of the types of spatial structure (TSS), the digression degrees, the composition of plants, the method of planting used, and the assessment of the state of plants in the subject park.

| No. | TSS | Digression degree | Plants | Planting method | Score | Notes |
|-----|-----|-------------------|--------|-----------------|-------|-------|
| 1   | 2a  | 3                 | Scots pine – 10, Common birch – 2 | Complex group | 3     |
| 2   | 2a  | 3                 | Scots pine – 10, Pyramidal poplar – 1 | Simple group | 3     |
| 3   | 2a  | 2                 | Scots pine – 10, Pyramidal poplar – 1 | Simple group | 3     |
| 4   | 1b  | 3                 | Scots pine – 10, Groups, massif | 2-3 |
| 5   | 2a  | 2                 | Common birch – 1, Mountain ash – 1, Ash–leaved maple – 1, Scots pine – 5 | Massif, complex group | 4 |
| 6   | 1a  | 3                 | Mountain ash – 2, Small–leaved elm – 1 | Massif, simple and complex groups | 3 |
| 7   | 1b  | 4                 | Norway maple – 4, Scots pine – 3 | Massif, complex group | 3 |
| 8   | 1b  | 4                 | Small–leaved elm – 1, Small–leaved linden – 1, Scots pine – 3 | Simple group, complex group | 3-4 | Drying of low branches, mechnical damage |
| 9   | 1b  | 4                 | Norway maple – 3, Small–leaved linden – 2, Norway maple – 10 | Simple group | 3 |
| 10  | 1b  | 3                 | Scots pine – 4, Common birch – 1 | Massif | 3 |
Table 4 shows that the closed type of the spatial structure with group-like distribution of trees prevails in the park. The open type represented by the pond, meadows and paths accounts for 5% of the park area. The major part of the park has reached the third degree of digression, and there are some areas of the 4th and 5th digression degrees accounting for 3% of the total area. That said, the park needs the regulation of recreational use.

The park was created on the site of a pine forest without any cutting work. For this reason, there are a lot of trees with dry branches and old dead stand in the park. The study found out 447 dry trees that must be removed.

The assessment of the state of plants and the overall park territory gives a picture of the gradual degradation of the park. The pines are dying out (the density and the size of crowns change). The overgrowth caused the deformation of crowns and stretching and curving of trunks of pines, drying of branches and complete die-out. The additional negative effect to the plants state comes from the anthropogenic loads due to accidental paths. The existing flatwork is also in poor condition and needs reconstruction.

All those negative factors have led to the loss of viability and decorative value of the plants which cannot effectively perform their sanitary, hygienic, recreational and architectural functions.

Upon the results of the study, it was intended to update the planning decision for the park and introduce the additional assortment of plants (figure 3).

| Table 4 | Tree Types | Complexity |
|---------|------------|------------|
| 11      | False acacia – 3 | Complex group, massif 4 |
|         | Small-leaved linden – 2 | Alley, solitaire 3 |
|         | Norway maple – 3 | |
|         | Scots pine – 4 | |
| 12      | Small-leaved elm – 4 |Massif 3-4 |
|         | Small-leaved linden – 3 | |
|         | Scots pine – 2 | |
|         | European mountain ash – 1 | |
|         | Common birch – 1 | |
| 13      | Small-leaved elm – 2 | Massif 3-4 |
|         | Scots pine – 2 | |
|         | Pyramidal poplar – 1 | |
|         | Common birch – 1 | |
| 14      | Common poplar – 2 | Groups 3 |
|         | Scots pine – 1 | |
|         | Scots pine – 5 | |
| 15      | Norway maple – 4 | Group 5 Mechanic al damage |
|         | Philadelphus coronaries – 1 | |
|         | Common birch – 3 | Massif, complex group 3 |
| 16      | Scots pine – 4 | |
|         | Vanhoutte spiraea | |
|         | Common birch – 2 | |
| 17      | Mountain ash – 2 | Complex group 3 |
|         | Ash–leaved maple – 2 | |
|         | Balsam poplar – 2 | |
| 18      | Scots pine – 2 | Simple group 3-4 Drying of branches |
|         | Ural false spiraea | |
| 19      | Scots pine – 9 | Simple group, massif 2 |
|         | Common birch – 4 | |
|         | Sorbus intermedia – 2 | |
| 20      | Scots pine – 2 | Complex group 4 |
|         | Vanhoutte spiraea | |

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Figure 3. The vision of improvement of the Dolphin Park.

Figure 3 shows the updated vision of improvement of the subject park and includes a motor road running along the reservoir. This road is designed in the general plan of the city as an alternate to the Leninsky Prospekt. It is intended to raise a part of this road running along the park to the level of three meters above the ground in order not to disturb the integrity of the park territory. This new vision preserves to the fullest extent the existing planning structure of the park and adds only one new alley leading from the main entrance to the embankment. There is another alley which leads from Perevertkina Street to the embankment, and these two alleys present the main paths of the park to the reservoir.

The main activity-related part of the park is a square with an amphitheater and a cinema area. The architectural decision echoes the relief of the park and provides for the harmonious flow-through into the service area under the overpass.

Visitors passing under the overpass get to the public embankment where they find a coffee-bar Mayak (Lighthouse). This bar visually connects the pier to the paddling pool area and a grid canopy which is designed as a resting site.

The analysis of the park zones allowed for the functional zoning. As a result, the park territory was divided into the following zones: a walking route, a kid playground and a quiet relaxing zone.

It is intended to divide the kid playground (figure 4) by ages using the relief (geo-plastics). Inside the playground, the following works are envisaged: the reconstruction of the symbolic sculpture Ryba-Kit (The Mother of All Fish), hanging of the birdhouses (for the purpose of environmental awareness of children), planting of a range of bright and fragrant perennial flowers – Paeonia, Spiraea japonica Little princess, Hydrangea paniculata Grandiflora (figure 5), houseleek (Semper vivum), asarabacca (Asarum europaeum), fescue (Festuca glauca).

Assortment of plants on the kids playground is as follows: Asarabacca (Asarum europaeum); Wolly woundwort (Stachys lanata); Houseleek (Semper vivum); Peony (Paeonia); Festuca Intense Blue (Festuca glauca Intense Blue); Japan Spiraea Little princess (Spiraea japonica Little princess); Hydrangea Grandiflora (Hydrangea paniculata Grandiflora); Fir-tree (Abies koreana Tundra).
Figure 4. Kid playground.

The decorativeness of woody plants cannot be assessed in isolation from their state; one should also take into account their quantity and resistance to urban effects [10,11].

A big part of the park will be occupied by the relaxing zone (Figure 5) and walking paths. There will be a winding path with alcoves nicely integrated into the landscape. The design stipulates the immersion into the nature: artificial ponds, decorative plants, rocks and hammocks will help feel closer to nature. The second storey might be formed by the common birches (Betula pendula) that help hide the warped pine trunks.

Assortment of plants in the relaxing area with hammocks is as follows: Common birch (Betula pendula); Common privet (Ligustrum vulgare); Vinca Panicle hydrangea Pink Diamond (Hydrangea paniculata Pink Diamond); Juniperus (Juniperus x-media Pfitzeriana Glauca); Pacific ninebark Dart’s Gold (Physocarpus opulifolium Dart’s Gold); Eastern arborvitae (Thuja occidentalis Brabant); Pacific ninebark Diablo (Physocarpus opulifolium Diablo).

Decorative plants around the hammocks will include soft wood species and shade-tolerant decorative blooming scrubs (panicle hydrangea, common privet, pacific ninebark). The storeyed structure of planting, hammocks and combination of hard and soft woods in the relaxing zone create a true oasis inside the pine forest. However, the implementation of this design will require a partial replacement of soil and sanitary cutting of some trees.

4. Conclusion
The purpose of this study is the detailed analysis of the planning structure and assessment of the existing plants in the subject park. On the basis of the analysis results, the updated planning decision has been proposed and the additional assortment of plants has been recommended – the one that differs from the existing assortment in its resistance to the urban impacts.

An optimal decision for the spatial structure of the green spaces, their variation and the rational distribution of the closed, open and semi-open spaces will provide for the light and airy territory.
Figure 5. Composition of plants in the relaxing zone

The assessment of the current state of the park and its vegetation has revealed an urgent need for the reconstruction of the territory, both in its planning structure and the assortment of plants. To reach the maximum aesthetic effect, there is a need for an integrated approach to the selection of the assortment of plants which should be sustainable to urban environments and perform the environmental protection functions, and, at the same time, have a high aesthetic value.

This vision of the improvement of the Dolphin Park, the proposed measures and the selection of plants for its functional zones can make it an attractive place for the residents of the Zhelezndorozhny district and other citizens of Voronezh.

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