To the analysis of qualitative indicators of plant vitality in assessing the value of urban green spaces

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Abstract The decrease in the plant vitality, and, therefore, the functionality of urban green spaces caused by a sharp deterioration in the growing conditions and the non-observance of scientifically based principles of planting planning and an absence of a reasonable plant material selection for specific objects. An unsystematic increase in the species and cultivar diversity of ornamental trees and shrubs occurs spontaneously, without considering the consistent work on introducing and cultivating new species and varieties. The use of imported, not adapted, and often poor-quality planting material leads to a decrease in the survival rate of new plantings and, as a consequence, to a deterioration of the condition of a green space in general.

1. Introduction
Green spaces contribute to the concentration of human and monetary capital in cities, creating favorable conditions for the growth of labor productivity, employment, living standards and quality of life (primarily in terms of education and health), including civil liberties, the development of innovations and the knowledge economy in general [1]. This approach is supported by most researchers and is corresponded with world practice, however, despite the large scope of green spaces built, their quality level in most cases is quite low. Based on this, it is necessary to identify the most modern approaches to solving this problem.

The notion stated in regulatory documents about the function of green spaces as a system of environmental restoration does not correspond to the current situation with existing landscape services in Russian cities. Undoubtedly, this is largely due to the negative impact of socio-economic changes in Russia in the early 1990s. The existing contradictions between the tasks declaration in methodizing the maintenance of green spaces and the results of this activity are associated with a number of objective reasons. Among them, a high level of soils and atmosphere pollution, infill development, high population density. Lately, the design of new green areas does not take into account the connection of urban vegetation with the microclimate features, carefully developed principles of plant selection are ignored, hence, the principles of landscaping of various territories have changed, the idea of the exceptional nature of the aesthetic component in urban landscaping has been established. At the same time, a decline in the ornamental qualities and vitality of the woody plants in green areas is noted, which, undoubtedly, is related to the problems of the selection of plant material to be used in landscape architecture objects.

The objective situation on the market of planting material in recent years is determined by:
- a plentiful supplies of plants of diverse species, varieties and cultivars from foreign nurseries, which creates an illusion of wide opportunities for their use;
- the lack of local nurseries (at least those that can provide the required groups of plants in the demanded amount);
- loss of parent stock plants for the propagation of plant material of domestic selection, as well as introduced species and cultivars of ornamental plants;
- the lack of a domestic system of modern introduction, acclimatization and cultivation of new species, varieties and cultivars of ornamental trees and shrubs.
It should be noted that one of the most important features of green infrastructure is multifunctionality [2]. The value of the landscape architecture object consists of a wide range of its qualities and functions such as the environment-forming role of the green space, the historical significance and recreational attractiveness, the land-use category, the absorption capacity of plants, the cost of restoring woody plants in a green space, the ecological state of the vegetation, and the amount of material costs for maintaining it in a viable state [3].

In addition to the undeniable environmental significance, the state of green spaces, to a large extent, determines the value of urban real estate, creates additional income. This aspect is the topic of interest of many studies conducted abroad, numerous methods for assessing the profit from urban green spaces are being proposed and tested [4].

Estimating the value of existing urban green spaces is an extremely urgent problem, leading to the decisions in a term of the maintenance of urban vegetation in optimal condition and preventing its degradation. In a comprehensive environmental survey of urban landscapes, the species composition, spatial distribution of green spaces, their growing condition, types of damage caused by different types of pests and diseases should be described.

2. Methods and Materials
Over the course of three years, from 2016 to 2019, surveys of woody vegetation were conducted in 48 garden squares and gardens ranging in size from 0.2 ha to 2.5 ha in various districts of St. Petersburg. The objects of the study were garden squares situated in historical part of the city (Admiralteysky and Central districts), in the largest districts of the city - Nevsky, located on two banks of the Neva, Kalininsky, and Vyborgsky, one of the oldest and, despite the industrial development, one of the greenest districts of St. Petersburg. When examining green spaces, the generally accepted method of total enumeration of trees and shrubs was carried out [5]. At the same time, a dendrometric and bioecological assessment was performed. Dendrometric assessment included recording the following parameters: plant index number in accordance with the inventory plan, species name, diameter of a trunk and crown, plant height.

Assessment of the quality state of the vegetation was carried out according to the generally accepted method. During the examination, deviations from the typical habitus of plants were assessed, as well as damages of a trunk, crown and root system.

The green areas selected for the study, due to the functions that they perform, structure and location features, can be considered as indicators of the condition of urban vegetation as a whole.

Most, about 50% of the examined garden squares and gardens are located inside residential quarters and designed for daily relaxing recreation and walks. In the list of objects of this group, the most typical examples are the former Italian Garden, the San Galli Garden in the Central District, the inner-quarter square at Engels Avenue, 15 and the garden square at Novorossiyskaya street, 20–22 in Vyborgsky district and the garden square on Dybenko street 23/1 in Nevsky district, etc.

The conditions for plants growth here are quite favorable - the green space is isolated from the negative effects of climatic and anthropogenic factors. The soil compaction and, unfortunately, vandalism can be considered here as the main limiting factors.

Another significant share of surveyed objects, about 40%, are the garden squares along the streets and motorways. This group includes the Nekrasovsky Garden in the Central District, the Fruit Garden in the Petrogradsky District, the Lithuanian Garden and the Alexander Matrosov Garden in the Vyborgsky District, etc. Many of these objects acquire through-movement paths, due to proximity to either metro stations, or major traffic intersections, both automobile and railway (Alexander Matrosov’s garden).

3. Results and Discussion
The complex of negative factors determining the state of plantings is much wider here. The defining factors are technogenic - exhaust gases, the influence of reagents, noise, thermal and electromagnetic pollution. The result is an excessive compaction of the topsoil, which impedes root breathing and absorption of the root, limiting the feeder zone of root systems [6, 7].

The natural features of St. Petersburg (good airing by winds, vast expanses of water, a large amount of precipitation) determine the potentially low air pollution of the city. However, the current wind regime exacerbates the effects of high and low temperatures, and also acts as a conductor of pollutants along streets which are parallel to the prevailing winds: west and northwest in the summer months and south and southwest in the winter. In St. Petersburg, meridionally oriented streets deliver polluted air from the southern industrial areas of the city to cleaner northern areas.
Thus, on the study objects the vegetation located in the immediate vicinity or at the intersection of motorways are subject to strong stress factors.

The third group of objects is the garden squares in front of administrative buildings and other socially significant objects: a square near the civil registry office of the Vyborgky district, a square in front of the Buff Theater in the Krasnogvardeisky district, Yusupovsky Garden in the Admiralteysky District, etc. Such squares are designed to act as 'foyer squares'. They are often open to a roadway side. The complex of adverse factors affecting the garden squares depends on the intensity of traffic load on this street, as well as of the recreational load.

In the course of the study, the species composition of the plantings of gardens and squares was assessed, the main limiting factors affecting the plants growth were identified, their condition was assessed. The following were recorded: the presence of trees with signs of weakening, drying out, crown retrenchment; the presence of foliage damage (necrosis, chlorosis, dominant pests, diseases); prevalence of the detected phenomena. In all the studied areas, there is a presence of both old-age trees and young plantings, which also allows us to compare the condition of vegetation.

During the study, the biometric parameters of more than 14 000 trees and shrubs were recorded, the total area of green areas included in the study was about 70 hectares.

The variety of species is represented by trees and shrubs from at least 10 plant families, at least 85% of which are introduced species.

Summarizing the survey data, we can conclude that the species composition of the vegetation of garden squares with an area of 1-2 ha, nevertheless, demonstrates a significant variety of plants - from 15 to 30 species. It should be noted that the vegetation is mainly represented by species, varietal diversity is practically absent, and the species diversity of trees is higher or approximately equal to the number of species of shrubs. The species composition in the studied areas largely coincides, which is connected, inter alia, with the principle of selection of research objects.

Deciduous species prevail in the studied green spaces. The share of species represented in the garden squares is ambiguous. The largest share is traditionally made up by the linden _Tilia cordata_ Mill. (35–62%), it was recorded at all examined objects of the city center. The following species are conspicuously represented at particular sites: _Acer platanoides_ L.– up to 60%, _Acer tataricum_ L. and _Acer ginnala_ Maxim.– up to 24%, _Quercus robur_ L. – 6–11%, _Betula pendula_ Roth. – up to 9%, _Sorbus aucuparia_ L. – 10–13 %, _Aesculus hippocastanum_ L. – 6–10% and _Fraxinus excelsior_ L. – 12%, _Ulmus glabra_ Huds. – 2,6–7% and _Ulmus laevis_ Pall. – 3,5–8,5%. The number of last species mentioned decreases sharply every year due to the massive damage to trees by the Dutch elm disease (DED, ophiostomiasis, graftiosis, wilt disease). Foci of the Dutch elm disease captured almost all areas of the city where elm plantings are found [8-10].

This ratio of species share in plantings can be traced in most gardens and squares of St. Petersburg. At the same time, differences in the composition of woody plants between the objects of city central and peripheral areas were revealed.

Trees of _Aesculus hippocastanum_ L. were recorded in almost all objects of the central districts, and in the peripheral districts such prevalent species were _Salix alba_ L., _Salix sarrea_ L. and _Salix fragilis_ L.

The trees, members of the _Rosaceae_ family, such as _Malus baccata_ L. Borkh., _Malus domestica_ Borkh., _Sorbus aucuparia_ L., and _Padus avium_ Mill, were found in 70% of the objects. Despite the fact that they occur singly, their presence significantly increases the aesthetic value of a green space.

It should be noted that _Padus avium_ Mill., as a short-lived plant, gradually leaves the plantings. At many studied areas it is presented as a plant spontaneously grown from shoots and does not represent ornamental value. As good alternative for _Padus avium_ Mill. can be _Padus maackii_ (Rupr.), which is more decorative and longer-living, as well as _Padus virginiana_ (L.) Mill., which is more resilient in urban environment.

Coniferous species at all sites are represented mainly by _Larix decidua_ Mill and _Larix sibirica_ Ledeb., _Picea glauca_ (Moench) Voss, which are recorded in the studied green spaces in both central and peripheral city districts. The share of conifers in the plantings of gardens and squares is small - no more than 5%. _Larix decidua_ Mill has the largest share. – up to 10% (Chernyshevsky garden).

In the green spaces of the peripheral city districts, the variety of conifers is wider. The specimens of _Pinus silvestris_ L. (up to 4–7%), as well as single trees of _Picea abies_ (L.) H. Karst. and _Thuja occidentalis_ L. were recorded in the plantings.

The largest share of the shrubs is made up by Cotoneaster lucidus Schlecht. - 4,5–73%. This prevalence is undoubtedly associated with the traditional use of this species in hedges. Nevertheless, it is worth noting that at present, mainly old plants of this species are found in observed green spaces.
plantings develop extremely slowly and are often in a weakened state. Also the following species are quite widely represented: *Syringa vulgaris* L - 11–47%, *Philadelphus coronarius* L. – 5–15%, *Rosa rugosa* Thunb. - 9–64%. Such species as *Symphoricarpos albus* L. with a share of up to 11%, *Berberis vulgaris* L. –36%, *Crataegus sanguinea* Pall. – up to 10% play an important role in in particular green areas.

The variety of sparse shrubs is quite large. These are several species of the genera *Spiraea* L., *Lonicer* L., *Philadelphus* coronarius L., *Viburnum opulus* L. and *Viburnum lantana* L., *Syringa josikaei* Jacq. (at certain sites, its share makes up to 10%), *Saragana arborescens* Lam., *Elaeagnus argentea* Pursh., *Ribes alpinum* L., *Cornus alba* L., *Physocarpus opulifolius* (L.) Maxim. Their share in the planting is 0.5–7%.

In the last decade, the diversity of ornamental shrubs in the studied green spaces has increased due to the introduction of cultivars of species such as *Berberis thunbergii* DC., *Chaenomeles maulei* (Mast.) C K Schneid, *Salix purpurea* L., *Hydrangea paniculata* Sieb, etc. Shrub masses of *Rosa × hybrida* Schleich began to be actively planted at front of administrative buildings and along highways, common cultivars in garden squares of the Central District are: 'Magic Meidiland', 'Rouge Meilove', 'Bonica', 'Lasevilliana'.

The role of shrubs in urban green spaces is extremely significant, thus, increasing their species and cultivar diversity is very important as well as enlarging the share of occurrence in plantings of squares, gardens and parks of St. Petersburg.

Among coniferous shrubs, diversity is also increasing. *Juniperus virginiana* L. occur singly in the garden square at the civil registry office of the Vyborgsky district and *Pinus mugo* Turra in the garden on Svetlanovskaya Square. Also in the green spaces of the peripheral city districts, primarily in the squares of residential areas *Juniperus sabina* L. and *Juniperus horizontalis* Moench are rarely found.

Regarding cultivar diversity of plantings of the studied objects, the occurrence rates of varieties and cultivars are extremely low, not more than 0.3%. Among trees, *Betula pendula* Roth ‘Youngii’, *Salix sarrea* L. ‘Pendula’, *Acer platanoides* L. (‘Royal Red’, ‘Crimson King’ and ‘Fascen Black’), *Salix alba* var. *sericea* Wimm. and *Salix fragilis* var. *spaerica* Hrysn. were recorded. The last two varieties are prevalent, their share in certain sites reaches 4–10%.

Cultivar variety of shrubs is represented wider, for example, several cultivars are represented by *Spiraea japonica* Desv. (‘Little Princess’, ‘Gold Flame’, *Berberis thunbergii* DC. (‘Atropurpurea’, ‘Green Carpet’), *Cornus alba* L. (‘Elegantissima’, ‘Sibirica’, ‘Sibirica Variegata’), *Salix purpurea* L. (‘Nana’/’Nana Gracilis’), *Caragana arborescens* Lam. ‘Pendula’. These cultivars are singly occurring in the plantings of recently restored or new objects, or in inner-quarter garden squares.

The following species are represented by one cultivar: *Spiraea × bumalda* Burv. ‘Anthony Waterer’, *Spiraea × cinerea* Zabel ‘Grefsheim’ (Spiraea × cinerea), *Berberis vulgaris* L. var. *atropurpurea*, *Thuja occidentalis* L. ‘Smaragd’, *Juniperus sabina* L. ‘Tamariscifolia’.

4. Conclusion

According to the results obtained in this study, most of the green spaces are characterized by good condition - from 42–70% in 22 of the 48 surveyed sites (table 1).

It should be noted that the prevailing damages to plants observed in all objects are crown retrenchment, frost cracks, mechanical damage, which most often develop in the vast majority of conifers. The same damages can be observed in plants of *Acer platanoides* L., *Quercus robur* L., *Aesculus hippocastanum* L., *Ulmus glabra* Huds. and *Ulmus laevis* Pall., *Betula pendula* Roth.

The most common type of damage of shrubs is various mechanical damages of such species as *Philadelphus coronarius* L., *Syringa josikaei* J.Jacq. ex Rchb.f. *Cotoneaster lucidus* Schlecht.

Numerous damage and malformations indicate that technological operations of green spaces maintenance, especially sanitary and thinning pruning, are not timely. The condition of plantations is significantly affected by high technogenic and recreational loads.

| Groups of study objects | Plantings condition, % | Characteristics of conditions at the research objects |
|-------------------------|------------------------|-----------------------------------------------------|
|                         | good | satisfactory | unsatisfactory |
| 1. Historical, central city | 75–95 | 3–18 | 0.1–4.3 |

The prevalence of old-growth trees and shrubs;
districts

2. Inner-quarter garden square of old city districts
   - 75–85
   - 9–22%
   - 4.8-10.2
   - pests and diseases complex; soil compaction; high class of air pollution.

3. Inner-quarter garden square of new city districts
   - 50–80
   - 10–36
   - 2.8–14
   - low survival rates of seedlings; deficiency after planting care; numerous mechanical damages, soil compaction;

4. Objects in harsh environmental conditions
   - 57–68
   - 27.5–40
   - 5–16
   - insufficient plant care; numerous mechanical damages; high class of aggregate (complex) pollution.

It should be emphasized that, despite the resemblance of indicators of the condition of green space vegetation and the recorded damages, some characteristic patterns of these indicators, for different groups of objects, were revealed.

The vegetation of objects of recent restoration, first of all - squares in front of administrative buildings and other socially significant objects has the best condition. The main reasons for the deterioration of plants at such sites are, first of all, the age that is quite significant for urban trees and shrubs, as well as adverse soil conditions - compaction and low fertility. At the objects of the recent restoration, not only work on pruning and plant treatment was carried out, but also part of the plants was replaced (Nekrasovsky Garden, the former Italian Garden), and in the garden square in front of the Buff Theater a complete replacement of the plantings was carried out. Up to 95% of woody plants are in good condition at such objects.

The vegetation of garden squares located inside residential areas have significantly different condition. There is a direct dependence of condition indicators from the recreational load together with the age of plantings in this group of objects. In the central districts of the city in such squares with a small area, old-growth trees and shrubs prevail. The regime of visiting and recreational load have settled here, therefore, the condition of vegetation is better - up to 75–85% of plants which were noted in good condition. In new districts, the context is the opposite - large open spaces, young plants (most often low value or poorly formed planting material was used) and intense recreational load. Moreover, the regularity and quality of green space maintenance in such objects is significantly worse. The number of plants in good condition is much smaller, and the range of values is greater - from 50% to 80%. The main problem here is the low survival rate of woody plants and their general weakening in harsh urban conditions.

The objects located in harsh environment are characterized by worst condition. The peculiarity of these objects is that they are unattractive for recreation and quite rarely visited, also because of inconvenient location near railway and motorways, industrial enterprises. In the Lithuanian Garden (33.6% of plants are in a weakened state), in the inner-quarter garden square of Engels Avenue, 15 (36.7% are weakened and 5% of plants are in an unsatisfactory condition), in a square on Ogneva street in unsatisfactory condition is 8% of plants. In the garden of Alexander Matrosov, most of the woody plants are in unsatisfactory condition, especially Acer platanoides L. (10%), Acer platanoides L. 'Royal Red' (35%), Fraxinus excelsior L. (17%), Aesculus hippocastanum L. (22%), Betula pendula Roth. (5-7%), almost 100% of Ulmus glabra Huds die back. The most common damages are mechanical damage caused by vehicles and vandalism, widespread pests and diseases, overly dense crowns, etc.

Besides, the qualities of the vegetation of such objects are neglected, the intensity of maintenance of the plantings is extremely low, and random. Mostly low-quality planting material is used for their creation and restoration. Such plantings are living less and characterized by poor ornamental qualities. In this group of objects, the lowest values of plants in good condition are noted, up to 57–68%.
The challenges of creating and maintaining green spaces in a large city are complex and diverse. They are exacerbated by global climate change, transport and technological load increase, urban development expand and lack of open spaces. The success of the solution depends on an objective knowledge of the features of green space creation and reliable estimates of the results of its functioning.

The data obtained can be taken into account while a scientifically based selection of adequate species composition, as well as during the optimal spatial planning of a green space. The results of this study should be considered when assessing biodiversity and the state of urban landscapes, which is important for predicting further changes, zoning the territory according to the level of technogenic pollution, and developing recommendations for assessing the resilience of the studied species in green spaces of the city, as well as to develop the list of woody plants suitable for creating green spaces in various ecological areas of the city.

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