Visual Landscape Analysis of the Territory of the Squares of the City of Orel and Assessment of the Dynamics of Urban Ecosystems According to the State of Woody Vegetation

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Abstract. The authors analyzed the territory of the squares in Orel to determine the influence of the types of spatial structures on the features of the functioning of the landscape objects, forecast the stability of the studied landscape and assess the dynamics of urban ecosystems according to the state of woody vegetation. In order to develop a scientifically-based design of sustainable urban ecosystems and to reconstruct urban objects of landscape architecture, a method for analyzing the territory of squares on the selected contours of the types of spatial structures (TSS) is proposed, which allows to identify positive and negative factors that affect the development of design solutions. It is found that for the majority of squares whose age of plantings is close to the limit in urban conditions, the closed type of spatial structure is typical. As a result of the analysis of the placement and the ratio of the types of spatial structures for a comprehensive assessment of territories, it was found that the closed type of spatial structure caused a decrease not only in the attractiveness, but also in the sanitary and hygienic role of landscape architecture objects. The most favorable conditions for the sustainable functioning of tree stands in urban squares are semi-open and open spaces.

1. Introduction

The main goal of current state socio-economic policy in urban planning is to improve the quality of life in the urban environment, as well as to create a favorable living environment and provide conditions for sustainable development on city territories \cite{1,2}. Strengthening and development of the spatial framework, preservation of the natural environment, development of green construction, preservation of historical and cultural heritage can be named as various factors for sustainable development of the city \cite{3}. Elements of mesostructures of the natural framework of the city are gardens, squares, and other green spaces within residential areas and neighborhood units. The more such territories, the higher the ecological efficiency of the city's landscaping system, which means the level of comfort in the urban environment for its residents.

The state of green spaces is an important indicator of the quality of urban environment, which largely determines the comfort of living. According to the Federal Law "On Environmental Protection" (2002), measures for the protection of green spaces are aimed at forming a single environmentally sustainable system, i.e., the green framework of the city \cite{4}. A city is considered to be...
ecologically safe if 10-12% of its area consists of natural landscapes that are not used for economic purposes [5]. The creation of sustainable, aesthetically valuable objects of landscape architecture for the harmonious development of the city is possible only with a scientific approach.

The total area of the city of Orel is 12,121 hectares. According to the city administration of Orel, the size of green areas and public plantings is 196 hectares, and the area of water bodies is 155 hectares. Thus, the level of “greening” of Orel is about 2% (1.6%) [6].

Squares play a significant role in improving sustainability of urban environments in terms of area occupied, the number of these sites, and the location within the city. In this regard, a comprehensive research of the territory of squares and an assessment of the dynamics of urban ecosystems is relevant to improve the environmental efficiency of the green spaces system in Orel.

The project of improvement of squares or parks arises from a scientifically-based study of the site and proceeds to the further development of this site. However, in fulfilled landscape reconstruction projects and in creating new ones, the stage of assessing and estimating the stability of the designed landscape is either completely absent, or is formal, i.e., based on methods for determining the stability of building and structures. At the same time, the main components that determine the quality of landscapes in urban conditions are vegetation and soil cover, the state of which can be used to measure the effectiveness of building a landscape structure, the relationship between the other components of the landscape (the lithological basis, hydrogeological and hydro chemical conditions, etc.) [8]. In turn, soil and vegetation are the most labile, most degradable components of urban landscapes, which determines the rate of dynamic changes in the landscapes themselves as a whole [9, 10].

**Objective.** The objective of this research is to analyze the territory of the squares of the city of Orel in order to determine the influence of the types of spatial structures on the features of the functioning of the landscape object, to predict the stability of the studied landscape and to assess the dynamics of urban ecosystems based on the state of woody vegetation.

**Research goals:**
1. Analyzing the placement and correlation of the types of spatial structures on the site;
2. Assessing aesthetic and sanitary conditions of the landscape;
3. Monitoring the condition of woody vegetation on the objects.

2. **Materials and methods**

During the research, the territories of 10 squares located in different districts of the city of Orel were studied. All the studied sites are characterized by a small area (up to 2 ha), are close to the maximum age of plantings in urban conditions, and have a typical location in the city plan: squares border on main roads with a significant traffic load. The location determines the negative dynamics of the state of urban ecosystems: the vegetation in the squares is heavily polluted with exhaust gases and heavy metals, as well as by the impact of noise from transport. The research was conducted in 2020.

For the development of scientifically-based design of sustainable urban ecosystems and the reconstruction of urban objects of landscape architecture, a method of studying the territory of squares on the selected contours of the types of spatial structures (TSSs) is proposed, which allows us to identify positive and negative factors that affect the development of design solutions. When analyzing the TSS of the squares, satellite images of objects were used. In the satellite images (in some cases, it is more appropriate to use a hybrid), the contours of the TSSs were distinguished: open, closed and semi-open. To determine the TSSs, the following criteria were used: closed – the crowns of individual trees do not variate, form a solid array (a sign of horizontal closeness); semi-open – the trees are separated from each other, the boundaries of the crowns of each tree are well-defined; open – an open space (a clearing, a pond, a playground, etc.). Visual landscape analysis of the site was carried out by a comprehensive aesthetic and sanitary and hygienic assessment for each type of spatial structure located on the territory separately, which led to an increase in the objectivity of the conclusions, in contrast to the assessment methods that offer an assessment of the territories of landscape architecture objects as a whole, without dividing into sections. The assessment of the dynamics of urban ecosystems based on the state of woody vegetation was also carried out separately by the types of
spatial structures with determining the qualitative state of trees and their viability category according to the standard methodology for monitoring the state of urban green spaces.

3. Results and discussion

Green spaces together with the relief, buildings form the spatial structure of the site of landscape architecture. The main classification feature of the spatial structure is the type of spatial structure (TSS), which is defined by the closeness of the canopy of tree stands, the density and the nature of their location on the object of landscape architecture.

The location of types of spatial structures (TSSs) on small-area objects of landscape architecture usually follow a certain logic: the closed TSS is located on the periphery of the site, and the open one is located in the center. The classic version of the square should be open and well-viewed. However, in the conditions of the urban environment and the existing system of care for green spaces in Russian cities, the spatial structure does not always retain the design characteristics and after 20-30 years of operation of the object changes to an unfavorable one.

As our research of the types of spatial structure in the territories of the squares of the city of Orel shows, the ratio of the TSSs on the object in most cases does not meet the urban planning requirements (Table 1).

| Square                        | TSSs, % open | semi-open | closed |
|-------------------------------|------------|-----------|--------|
| Named after N. N. Polikarpov  | 15         | 21        | 64     |
| “Tramvainiy”                  | 36         | 29        | 35     |
| “Burevestnik”                 | 40         | 50        | 10     |
| “400th anniversary of Orel”   | 55         | 30        | 15     |
| Named after L.N.Gurtjev      | 21         | 10        | 69     |
| Named after I.A.Bunin         | 25         | 10        | 65     |
| “Komsomolsky”                 | 15         | 25        | 60     |
| Writers of Orel               | 40         | 30        | 30     |
| OSU Square                    | 10         | 30        | 60     |
| Named after V. V. Mayakovsky  | 50         | 40        | 10     |
| average                       | 30.7       | 27.5      | 41.8   |

The data in Table 1 shows that the majority of the studied squares are dominated by closed TSSs; on average, this type of spatial structure is found on 41.8% of the square area. In such spaces, there is a complete horizontal closeness of the canopy, trees grow in conditions of insufficient food area, lighting, which in an unfavorable environmental situation aggravates the growing conditions of plantings and cannot but cause their weakening. The squares with a predominance of closed TSSs are unnecessarily shaded, the existing dominants almost do not stand out against the background of plantings. Also, thickened plantings negatively affect the system of viewpoints. Closed areas are placed evenly throughout the territory, which is caused by the lack of regular maintenance of tree stands and the significant age of the trees.

The location of open (30.7% of the total area of squares) and semi-open (27.5%) TSSs is haphazard and random. At the same time, these landscapes show an improvement in the growing conditions of trees: the boundaries of the crowns of each tree, and therefore the feeding area, are well defined.

The aesthetic assessment of the landscape (the maximum value is 50 points) is established based on visual-comparative conclusions and is determined by four indicators: the surrounding framework (plants, water surfaces, architecture), viewpoints (saturation, uniqueness, depth of perspectives); relief (exposure, % of slope); soil and vegetation cover (condition, diversity). The surrounding framework is evaluated by the highest number of points as the most important factor.
For the characteristics of the sanitary and hygienic state of the sites, their suitability for performing sanitary and hygienic and health-improving functions is assessed: from the maximum level of class 1 to the minimum level of class 3.

Table 2. Aesthetic and sanitary and hygienic assessment of the squares of the city of Orel.

| Square                     | Aesthetic assessment of the TSSs, points | Sanitary and hygienic assessment of the TSSs, class |
|----------------------------|-----------------------------------------|--------------------------------------------------|
|                            | opened | semi-opened | closed | opened | semi-opened | closed |
| Named after N. N. Polikarpov “Tramvainyj” | 29     | 41          | 16     | 2      | 2           | 3      |
| “Burevestnik”              | 41     | 39          | 15     | 1      | 1           | 1      |
| “400th anniversary of Orel” Named after L.N.Gurtjev | 48     | 33          | 37     | 2      | 2           | 2      |
| “Komsomolsky” Orel writers | 42     | 31          | 26     | 1      | 2           | 2      |
| Named after I.A.Bunin OSU Square | 39     | 30          | 12     | 2      | 2           | 3      |
| “Komsomolsky” Mayakovsky   | 28     | 36          | 18     | 2      | 2           | 3      |
| Orel writers               | 25     | 43          | 32     | 2      | 2           | 3      |
| OSU Square                 | 29     | 43          | 30     | 2      | 2           | 3      |
| Named after V. V.          | 38     | 29          | 12     | 2      | 1           | 2      |
| average                    | 33.4   | 36.1        | 21.9   | 1.8    | 1.8         | 2.5    |

The findings reveal that the semi-open TSS (36.1 points) and open TSS (33.4 points) receives the highest number of points and, accordingly, a high aesthetic rating. The lowest aesthetic rating of the closed TSS is 21.9 points, which is due to the difficulty of identifying viewing site and poor visibility; and inhibition of the growth of not only trees, but also ground vegetation, which in most cases is represented by sparse grass with poor species diversity.

When conducting a sanitary and hygienic assessment of various TSSs, it was revealed that the closed TSSs also correspond to the worst rating (2.5 class), which is associated with a decrease in the suitability for performing sanitary and hygienic functions in weakened and damaged plants.

The most characteristic component of urban ecosystems, which integrally reflects changes in ecosystems, is the stand of trees (tree stands). The monitoring of the state of green sites is carried out to assess the state of green spaces and its dynamics, including negative ones [12].

When studying the composition and condition of the vegetation of the squares, it was revealed that the tree sites are dominated by hardwoods, including *Tilia cordata* Mill, *Sorbus aucuparia* L., *Acer negundo* L., *Acer platanoides* L., *Aesculus hippocastanum* L. Among the coniferous trees, the most wide-spread are *Picea abies* (L.) Karst., *Picea pungens* Engelm. and *Thuja occidentalis* L. Hedges are dominated by *Cotoneaster lucidus* Schlecht., *Syringa vulgaris* L., a species of *Spiraea* s.p., *Juniperus sabina* L.

To determine the influence of the type of spatial structure on the stability of trees, we carried out a monitoring of the species found in all the studied squares. The average score of the quality status of tree species is shown in Table 3.
Table 3. Influence of the types of spatial structures on the resistance of tree stands.

| Species                      | Quality conditions of trees depending on the TSSs |
|------------------------------|-----------------------------------------------|
|                              | Open     | Semi-open | Closed  |
| **Tilia cordata** Mill       | 3.5      | 3.7       | 2.9     |
| **Acer negundo** L.          | 3.9      | 4         | 3.4     |
| **Sorbus aucuparia** L.      | 3        | 3.1       | 2.6     |
| **Acer platanoides** L.      | 3.8      | 3.8       | 3.3     |

According to the research results, the majority of species in open and semi-open spaces of public gardens are in good condition without signs of weakening - their condition is estimated at 3.5-4 points. Only mountain ash, which is less stable for urban growth conditions and loses its viability faster, is characterized by a satisfactory condition in open spaces, which worsens with an increase in the closeness of plants (in a closed TSS, the score decreases to 2.6 points). It was found that in closed sites, on average, the foliage of trees is often lighter than usual, the crown is slightly greener, the growth is weakened compared to normal, there are about 25% of dry branches, which corresponds to a satisfactory assessment (3.4-2.6 points) and a weakened quality condition.

4. Conclusion
Within the majority of squares in Orel with the age of plantings close to the limit in urban conditions, a closed type of spatial structure is typical; on average, this type of spatial structure prevails on 42.8% of the total area of the studied squares.

As a result of the analysis of the location and the ratio of the types of spatial structures for a comprehensive assessment of territories, it was found that the closed type of spatial structure caused a decrease not only in the attractiveness, but also in the sanitary and hygienic role of landscape architecture objects.

The most favorable conditions for the sustainable functioning of tree stands in urban squares are formed in semi-open and open spaces.

It is recommended to analyze the types of spatial structures when developing a research-based design and reconstruction of urban landscape architecture sites. The analysis provides a more objective forecast for the stability of urban ecosystems.

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