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Vitality as an Indicator of Aesthetic Quality: An Initial Assessment of Urban Trees in Akademski Park, Belgrade

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ABSTRACT

Urban green spaces are essential for enhancing ecosystem services, biodiversity, and human well-being, yet their sustainability relies on the long-term vitality and aesthetic quality of trees. This study examined changes in tree vitality and decorativeness in Akademski Park, Belgrade, Serbia, over a ten-year period (2015–2025) to assess species-specific responses to urban environmental stress. Data were collected using the basic Visual Tree Assessment (VTA) method, evaluating 132 trees in 2015 and 121 in 2025 across 22 species. Both vitality and aesthetic values were rated on a five-point scale, and differences were tested using the Wilcoxon signed-rank test for paired samples. Results showed a slight overall decline in vitality (from 3.9 to 3.7) and a stable decorativeness score (3.6–3.7). Significant reductions in vitality were observed for *Cedrus atlantica* (p=0.002), while *Tilia cordata* showed improvement (p=0.037). *Platanus × acerifolia* exhibited a significant increase in decorativeness (p=0.040), confirming its adaptability to urban conditions. Other species displayed minor or non-significant changes, indicating general stability in tree health and visual quality. The findings suggest that Akademski Park has maintained its ecological and aesthetic function despite environmental pressures. Long-term monitoring and species-specific management are essential for sustaining urban tree vitality and optimising the resilience of green infrastructure under changing climatic conditions.

Keywords: long-term monitoring; tree selection; urban trees; vitality; decorativeness

INTRODUCTION

Urban green spaces are essential components of sustainable cities, providing ecosystem services that mitigate climate change impacts, reduce air pollution, regulate urban temperatures, and support human well-being and biodiversity (Lin and Li 2025). In addition to ecological benefits, trees make a significant contribution to the cultural landscape through their ornamental value. However, ornamental appeal is often associated with a physiological condition. Urban greenery faces multiple challenges, including pollution, habitat fragmentation, compacted soils, and increasing pest and disease pressures that threaten the vitality of urban trees and shrubs (Ćirković-Mitrović et al. 2016). Tree vitality, representing health and vigour, may directly influence aesthetic perception, but long-term data are limited. The objective of this study was to quantify changes in vitality and ornamental value across species over a 10-year period and to assess their correlation, providing insight for horticultural management in urban parks.

Akademski Park, located in the historic core of Belgrade, Serbia, is a notable example of multifunctional green infrastructure. Established in the 19th century on the grounds of a former Turkish cemetery and marketplace, the park, although not a classical English landscape garden, originally featured a spontaneous and informal structure in the spirit of the landscape design styles of that period. The park was officially protected as a natural monument of botanical character in 2007 due to its ecological, historical, and cultural significance. Over time, its design and dendroflora have undergone considerable transformation. The park originally hosted 21 tree species—17 deciduous (77.4%) and four coniferous (22.6%)—alongside decorative shrub species such as *Berberis thunbergii* DC., *Symphoricarpos albus* (L.) S.F. Blake, and *Cotoneaster horizontalis* Decne. (Krstić et al. 2021).

A major revitalisation effort in 2015, led by the Public Utility Company "Zelenilo Beograd", involved the removal of numerous ageing or diseased trees—including *Aesculus hippocastanum* L., *Catalpa bignonioides* Walter, *Paulownia tomentosa* (Thunb.) Steud., and the historically significant *Sophora japonica* L., as well as the replacement of several shrubs. In their place, new plantings included *Platanus* x *acerifolia* (Aiton) Willd., *Fraxinus ornus* L., *Pyrus calleryana* Decne., *Liriodendron tulipifera* L., and ornamental species such as Photinia x fraseri Dress and cultivated roses. This restructuring increased the number of deciduous species to 18 but halved the conifer diversity, now represented by only two taxa (*Cedrus atlantica* (Endl.) Manetti ex Carrière and *Pinus nigra* Arn.).

Notably, the last and oldest Sophora japonica tree, believed to date from the park's original layout, was removed in 2008 due to safety concerns and later commemorated through the "Sophora Bench" sculpture—a symbol of the park's living heritage.

Today, the dendroflora of Akademski Park is assessed as being in satisfactory condition, with a mean health score of 3.25 out of 5. However, 25% of trees are rated as being in poor or very poor condition, and infestations of pests such as *Coccus hesperidum* Linnaeus, *Tetranychus urticae* C. L. Koch, *Tortrix viridana* Linnaeus, as well as fungal infections like powdery mildew (*Erysiphe* spp. R.Hedw. ex DC.) have been recorded (Mladenovic et al. 2016).

MATERIALS AND METHODS

The study was conducted in Academic Park (44.81953° N; 20.45784° E), a city park in Belgrade, the capital of the Republic of Serbia.

The study was conducted in 2015 and 2025. A total of 132 trees were identified and examined across the designated study area in 2015, and 121 in 2025. Data were collected using the basic Visual Tree Assessment (VTA) method (Mattheck and Breloer 1994). The tree condition was evaluated based on vitality and aesthetic quality. Aesthetic quality (decorativeness) was evaluated on a five-point scale, and vitality was assessed using measurements of height, trunk length, and crown width, and also rated on a five-point scale (Table 1) (Stojanović et al. 2021).

A detailed visual inspection was performed to assess the overall condition of each tree, with particular attention to crown structure, foliage density, and the presence of phytopathological symptoms, mechanical damage, or insect infestations.

For each species, mean changes and the proportions of trees that improved, declined, or remained unchanged were calculated. Differences between years were tested using the non-parametric Wilcoxon signed-rank test for paired samples, suitable for ordinal data that may not follow a normal distribution. Species with fewer than two observations were excluded from testing. Statistical analysis for this test was performed using R programming language version 4.3.2 (R Core Team 2024).

Figure 1. Map of the Academic Park location.

Table 1. Ranks given for tree vitality and decorativeness.

Rank	Criteria for Evaluating Tree Vitality	Criteria for Evaluating Tree Decorativeness
1	A dead or dying tree; deformed, diseased, decaying, broken, or severely damaged, with no potential for recovery.	A visually unbalanced, asymmetrical tree that disrupts the overall spatial impression. Lacking distinct colour, variation, or dynamics, with poorly defined form and structure.
2	Still vital with any mechanical or health damage. Trees with a missing part of the crown. Extremely damaged tree that can survive.	A tree with an uneven, disproportionate silhouette and poorly defined form, showing signs of mechanical or health damage. Missing parts of the crown, with weak color harmony and an unbalanced relationship between mass and volume.
3	A damaged tree that can be revitalised through proper maintenance. Tree with a distinctly shaped crown. Tree with a moderate level of disease or mechanical damage.	Tree with a clearly outlined crown visible in silhouette. Lacking colour variation and visual interest. Positioned in a way that appears disproportionate or poorly integrated within the surrounding space.
4	A healthy tree showing slight signs of disease or pest damage. Minor defects are present but can be easily corrected through proper maintenance.	Tree with a visually harmonious shape and only slight aesthetic imperfections. Displays a well-balanced interplay of colour, form and volume.
5	Completely healthy and undamaged tree. Tree of exceptional vitality and strong adaptation to the surrounding environmental conditions.	A visually striking and highly ornamental tree that exhibits clear proportion and symmetry consistent with its species. Distinct in colour and form, it enhances the space through its elegant lines, structure, and overall appearance.

RESULTS

In the Academic Park (Table 2), a total of 22 tree species with 130 individual trees were recorded in 2015. Deciduous species predominated, with 19 species (including one evergreen) comprising 111 individuals, or 85% of the total dendroflora. Conifers were represented by three species with a total of 19 individuals, accounting for 15% of the trees. Among the deciduous species, *Platanus* × *acerifolia* was the most abundant with 20 individuals, followed by young specimens of ornamental pear (*Pyrus calleryana*, 19), *Sophora japonica* (18), *Aesculus hippocastanum* (12), *Tilia* spp. (8), *Gleditsia triacanthos* (7), and evergreen *Photinia* × *fraseri* (6). All other deciduous species were represented by less than six individuals. Among conifers, species of the genus *Cedrus* sp. dominated with 18 individuals, while *Pinus nigra* was represented by only one tree (Table 2).

In 2025, a total of 21 tree species comprising 121 individual trees were recorded. The number of conifer species increased, now represented by four species with a total of 21 individuals, accounting for 17% of all trees. Deciduous species remained dominant, with 17 species, including one evergreen, comprising 100 individuals, or 83% of the dendroflora. *Platanus* × *acerifolia* and *Sophora japonica*, with 19 individuals each, continued to be the dominant deciduous species, followed by *Pyrus calleryana* (16), *Aesculus hippocastanum* (12), *Tilia* spp., and *Gleditsia triacanthos* (7 each), while all other deciduous species were represented by fewer individuals (Table 2). Among the conifers, species of the genus *Cedrus* sp. continued to dominate with 18 individuals, while *Picea omorika* was represented by two individuals, and *Pinus nigra* by only one tree (Table 2).

A comparative analysis of mean vitality and decorativeness values for tree species assessed in 2015 and 2025 revealed moderate interspecific variation and several notable trends. Across all species, the mean vitality value slightly decreased from 3.9 to 3.7, while the mean decorativeness value remained nearly unchanged (3.6 in 2015 vs. 3.7 in 2025).

Species-specific comparisons indicated that *Cedrus atlantica* experienced the most pronounced decline in vitality, from 4.8 to 3.8, accompanied by a smaller reduction in decorativeness (from 4.3 to 3.8). Similar but less marked decreases in vitality were recorded for *Sophora japonica* (4.4→3.7) and *Pyrus calleryana* (4.1→3.8). In contrast, several species showed improvement between years, most notably *Tilia cordata* (2.9→3.6), *Quercus robur* (2.7→3.7) and *Tilia tomentosa* (3.0→4.0).

The only species that exhibited a clear increase in both vitality and decorativeness and maintained a relatively large sample size was *Platanus* × *acerifolia*, whose vitality improved from 3.9 to 4.2 and decorativeness from 3.4 to 4.3. Some species, such as *Catalpa bignonioides*, *Celtis australis*, *Fraxinus ornus* and *Pinus nigra*, showed stable values across both years, indicating consistent condition and minimal change.

Across all species, changes in tree vitality and decorativeness were generally modest, with most species showing small positive or negative shifts between 2015 and 2025. Significant declines in vitality were observed in *Cedrus atlantica* ($p=0.002$), while a significant improvement in vitality was found for *Tilia cordata* ($p=0.037$). Decorativeness showed a significant increase only in *Platanus* × *acerifolia* ($p=0.040$). For other species, changes were not statistically significant.

The bars represent the average change in vitality (green) and decorativeness (blue) scores per species. Positive values indicate improvement, while negative values indicate decline. Asterisks (*) denote statistically significant changes based on the Wilcoxon signed-rank test ($p<0.05$, $p<0.01$). The dashed horizontal line at zero marks no change between the two observation periods. Species with ≥3 trees are displayed in bold on the y-axis.

Table 2. Overview of tree species in the Academic Park and their mean vitality and decorativeness values in 2015 and 2025.

No.	Scientific Name	2015	Mean Vitality Value	Mean Decorativeness Value	2025	Mean Vitality Value	Mean Decorativeness Value
1	*Acer pseudoplatanus* L.	1	3	3	/	/	/
2	*Aesculus hippocastanum*	12	2.6	2.8	12	3.2	3.3
3	*Betula verrucosa* Roth.	1	2	2	/	/	/
4	*Catalpa bignonioides*	1	3	3	1	3	3
5	*Cedrus atlantica*	17	4.8	4.3	17	3.8	3.8
6	*Cedrus deodara* (Roxb.) G.Don	1	3	3	1	4	4
7	*Celtis australis* L.	1	4	4	1	4	4
8	*Fraxinus ornus*	1	3	3	1	5	5
9	*Ginkgo biloba* L.	1	5	5	1	4	4
10	*Gleditsia triacanthos*	7	3.9	3.9	7	3.7	3.7
11	*Juglans nigra* L.	2	2.5	3	2	2.5	3
12	*Koelreuteria paniculata* Laxm.	4	3.5	3.2	3	3	3
13	*Liriodendron tulipifera*	1	3	4	1	4	4
14	*Photinia × fraseri*	6	4.5	4.5	2	3	3
15	*Picea omorika* (Pančić) Purk.	/	/	/	2	3	3
16	*Pinus nigra*	1	3	3	1	3	3
17	*Platanus x acerifolia*	20	3.9	3.4	19	4.2	4.3
18	*Prunus cerasifera* var. *atropurpurea* Jaeger	3	5	5	4	3.5	3.5
19	*Pyrus calleryana*	20	4.1	3.35	16	3.8	3.6
20	*Quercus robur* L.	4	2.7	2.5	3	3.7	3.7
21	*Sophora japonica*	18	4.4	4.3	19	3.7	3.8
22	*Tilia cordata* Mill.	7	2.9	3.4	7	3.6	3.6
23	*Tilia tomentosa* Moench	1	3	3	1	4	4
	Total values	**130**	**3.9**	**3.6**	**121**	**3.7**	**3.7**

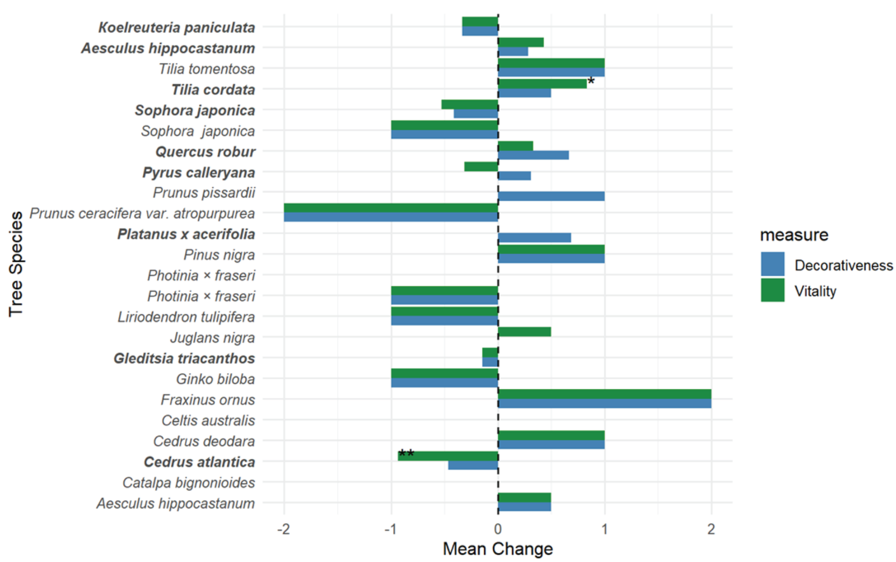

Figure 2. Mean change in vitality and decorativeness (2015–2025) by tree species.

DISCUSSION

The results indicate that the overall vitality and decorativeness of the analysed urban tree species remained relatively stable between 2015 and 2025, with only modest interannual variation.

Statistical evaluation was performed using the Wilcoxon signed-rank test for paired samples, an appropriate non-parametric method for ordinal data that may not meet the assumptions of normality. This test considers both the direction and magnitude of changes between years. Trees with missing values for one of the time points were excluded, and species represented by fewer than two observations were omitted from the analysis. As multiple species were tested separately, p-values were interpreted cautiously in an exploratory context, without formal correction for multiple comparisons.

Significant declines in vitality were observed for *Cedrus atlantica* (p=0.002), while *Tilia cordata* exhibited a significant improvement in vitality (p=0.037). In terms of decorativeness, only *Platanus* × *acerifolia* showed a statistically significant increase (p=0.040). For other species, changes in either vitality or decorativeness were not statistically significant, indicating relatively stable conditions over the ten-year period. Median changes were generally small, suggesting that the significant findings reflect consistent but limited shifts rather than large-scale transformations.

The decline recorded in *Cedrus atlantica* is likely related to its known sensitivity to drought stress, increasing urban heat, and reduced air humidity, which can limit its long-term performance in city environments (Kunert et al. 2021, Linares et al. 2011, Touchan et al. 2008).

Conversely, the improvement observed in *Tilia cordata* and *Quercus robur* reflects their better adaptability to urban stressors, robust root systems, and resilience to pollution (Kisvarga et al. 2025, Krutovsky et al. 2025, Rolando et al. 2025, Martynova et al. 2020).

The positive trend in *Platanus* × *acerifolia* confirms its well-documented tolerance to pruning, compacted soils, and fluctuating moisture conditions, making it one of the most reliable urban tree species for maintaining vitality and visual appeal over time (Bachofen et al. 2025, Esper et al. 2023, Mengfan et al. 2019, Li et al. 2019). Stable values in *Catalpa bignonioides*, *Celtis australis* and *Fraxinus ornus* further suggest strong ecological stability and successful adaptation to local microclimatic conditions (Magliocco and Sabbion 2025, Čukanović et al. 2024, Pikhalo and Boridchenko 2022)

Two individuals, *Acer pseudoplatanus* and *Betula verrucosa*, were no longer present in 2025, as they had withered or been removed during the monitoring period. The loss of these two species slightly reduced overall species diversity, but the introduction of *Picea omorika* partially compensated for this decline by increasing the proportion of conifer species within the urban tree composition.

Despite isolated vitality declines in certain taxa, the absence of a broader downward trend implies that the monitored population as a whole remains in good condition. The slight overall reduction in vitality may reflect normal ageing processes or environmental stress accumulation, while stable or increased decorativeness indicates that trees continue to fulfil their visual and landscape functions effectively.

These findings highlight the importance of long-term monitoring in urban tree management. Differences among species underscore the necessity of species-specific strategies for planting and maintenance to sustain both ecological function and aesthetic value of urban green spaces under changing climatic and environmental conditions (Kecman et al. 2025, Roman et al. 2014).

Although most species showed no statistically significant change, this stability is itself ecologically meaningful, suggesting that a large portion of the urban tree population maintained its condition despite ongoing environmental pressures. Non-significant results therefore support the idea of relative persistence in urban tree performance over time, rather than a generalised decline.

CONCLUSIONS

Across all examined species, changes in tree vitality and decorativeness between 2015 and 2025 were generally modest, with most species showing only small positive or negative shifts. The proportions of trees that improved, declined, or remained unchanged varied among species, indicating species-specific responses to urban environmental conditions.

The park has retained its vital ecological and aesthetic functions. Mature specimens, including those over a century old, demonstrate notable adaptability to harsh urban conditions. The park contributes to the reduction of solar radiation, lowers air temperatures during summer, and filters urban pollutants, making it a critical environmental and cultural asset in a densely populated metropolis. As urbanisation and climate stressors intensify, the conservation and adaptive management of spaces such as Akademski Park will become increasingly important for urban resilience and quality of life. Overall, the analysis highlights the importance of long-term monitoring of individual species to detect subtle vitality trends that may precede visible decline. Differences among species emphasise the need for species-specific management strategies to sustain tree health and aesthetic value in urban landscapes under changing climatic conditions.

The results of this study can serve as a practical basis for selecting resilient and visually appealing tree species in future urban planting schemes. Integrating vitality assessments into routine park maintenance and planning processes can improve early detection of decline and optimise resource allocation. Future research should further explore predictive models linking environmental stressors, vitality dynamics, and ornamental value to support evidence-based urban forestry policies.

Author Contributions

Author Contributions: MS, VM, MDM conceived and designed the research, MS, VM, SV and MŽM carried out the field measurements, PZ, MDM, OJ processed the data and performed the statistical analysis, MS, VM, MDM wrote the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study, in the collection, analyses, or interpretation of data, nor in the writing of the manuscript and in the decision to publish the results.

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