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Original article

Allergenicity of tree avenues in an urban district of Novi Sad, Serbia

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ABSTRACT

Tree avenues in urban settings represent an important element of urban green infrastructure (UGI), providing ecological, aesthetic, and social benefits. However, they can also contribute to allergenic risks that affect public health. This study aimed to analyze the tree species distribution within tree avenues in the Nova Detelinara district of Novi Sad, Serbia, with a particular focus on their allergenic potential. A field inventory was conducted during April 2025, which identified 849 individual trees belonging to 39 species. Each species was categorized by its allergenic potential based on data in the literature, and an Index of Allergenicity of Urban Green Zones (I_{UGZA}) was calculated for the detected individuals found in 14 observed streets to assess the overall allergenic risk of the species composition within the area. Analysis of the allergenic potential of the identified species showed that most species had low (41%) or moderate (31%) allergenic potential, with only one species which was very low. In the observed UGI element, trees with moderate allergenic potential were the most abundant (48%), followed by high (31%) and low (15%) potentials, while very high and very low allergenic potential were present in 6% and one tree, respectively. The I_{UGZA} index values ranged from 0.01 to 0.37, classifying species composition in Stevana Mokranjca Street as high-risk ($I_{UGZA} > 0.3$), whereas all other streets fell within the low-risk category ($I_{UGZA} < 0.2$). The findings contribute to the development of more informed, local- and city-level approaches to establishing and managing the use of UGI, as well as species selection strategies that balance ecological criteria with public health considerations.

KEY WORDS: urban green infrastructure (UGI), allergenic potential of tree species, I_{UGZA} index, pollen allergy, public health

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1. Introduction

In urban environments, green spaces represent one of the most significant links between humans and nature, and as such, they play a crucial role in preserving both the ecological values of the city and the psychophysical health of residents (PERKOVIĆ, 2017). It is projected that by 2050, as many as 68% of the world's population will live in cities (UNITED NATIONS, 2018). For this reason, ensuring quality of life through the planned development of functional and sustainable urban green infrastructure (UGI) is essential.

UGI is defined as a functionally connected system of diverse green spaces, which enables the preservation of biodiversity, regulation of microclimatic conditions, improvement of air quality, and positive impacts on human health and quality of life (ANASTASIJEVIĆ & VRATUŠA, 2000; KONDO ET AL., 2018; JENNINGS ET AL., 2024; DERDOURI ET AL., 2025). Therefore, urban planning and reconstruction should consider all existing and planned green spaces, forming an optimal system that integrates ecological, bioclimatic, functional and aesthetic roles into a unified whole (Maričić, 2007).

As part of the UGI, tree avenues have an important role in urban development and the shaping of city environments, making them an essential structural element (Kritovac, 2004). They define movement paths, frame spaces, separate zones of different or similar functions, and guide visual perception (Dobrilovič, 2009). In urban areas, they can form a network of green corridors linking various elements of the UGI. Tree avenues provide numerous ecosystem services (Dobrilovič, 2009; Osseni, 2021; Aravindhan et al., 2024), influence air temperature, quality and airflow (Gromke & Blocken, 2015; Hong et al., 2017), mitigate traffic-related pollution (Gromke & Blocken, 2015; Aravindhan et al., 2024; Kalozi et al., 2025), contribute to carbon sequestration (Desai & Nandikar, 2012), and additionally have an aesthetic role in the space (Rosłon-Szeryńska & Wojtyna, 2014; Aravindhan et al., 2024). Hence, establishing a greater number of tree avenues is essential due to their multiple benefits (Osseni, 2021).

In contrast to the previously mentioned positive functions of avenue trees in urban areas, several negative impacts on public health have also been observed, the most significant being the potential of certain species to trigger allergic reactions in many people (Mihailović et al., 2016; Cariñanos et al., 2017; Calatayud & Cariñanos, 2024; Laala et al., 2025), most commonly manifesting as rhinitis (Asam et al., 2015; De Weger et al., 2024), sneezing, itching, nasal congestion, and rhinorrhea (Cariñanos et al., 2014). Allergenic plants are mainly adapted to anemophilous pollination, during which pollen, with pronounced allergenic properties, is produced and released in extremely large quantities (Mihailović et al., 2016; De Weger et al., 2024). In urban environments, these problems are further intensified due to the presence of urban heat islands and worsening air quality (Cariñanos & Marinangeli, 2021), while the interaction of pollen with other pollutants may intensify symptoms in sensitive people (Cariñanos et al., 2017).

The allergenicity of tree species should be a key criterion in planning and managing urban green spaces, particularly in areas of daily human activity (Cariñanos et al., 2019). Although it represents only one factor in selecting plant material, its role becomes crucial when balancing the benefits provided by tree species and their potential negative impacts on public health. In residential areas, species, cultivar, sex, and planting location strongly influence allergen exposure (Nowak & Ogren, 2021), and since pollen is present both outdoors and indoors, limiting highly allergenic species is one of the most effective preventive measures (De Weger et al., 2024). In this context, assessing the allergenicity of tree species represents an important planning consideration for integrating public health aspects into UGI management at the city level.

The aim of this study was to analyze species within the tree avenues in the district of Nova Detelinara in Novi Sad, Serbia, with a focus on their allergenic potential, as well as examining the representation and spatial distribution of allergenic species in tree avenues across different streets. Particular emphasis is placed on categorizing species by their allergenic potential, analyzing their distribution by street, and assessing public health risks using the Urban Green Zone Allergenicity Index (Cariñanos et al., 2014). This approach highlights the importance of careful species selection when establishing tree avenues, by considering their allergenicity and possible impact on public health and quality of life. The study thus has the potential to serve as a practical tool for city authorities, guiding future tree planting, supporting the management of tree avenues, and contributing to the development of a healthier and more sustainable UGI.

2. Materials and methods

2.1. Study area

Research was conducted in the urban district of Nova Detelinara, Novi Sad, Serbia (Fig. 1), located between latitudes 45°15'37'' and 45°15'33'' N and longitudes 19°48'33'' and 19°49'22'' E, covering an area of approximately 49 ha. Novi Sad is the second largest city in Serbia, with a population of around 367,000 inhabitants, and features a mix of residential, commercial, and green spaces. According to the General Urban Plan of Novi Sad until 2030, the district is classified as a residential zone of apartment buildings, with medium population density and predominately medium- to high-rise structures (3 to 6-storey buildings). Within the area, there is one preschool and one secondary school, with plans for an additional preschool, as well as primary and secondary schools. The study area provides a representative example of the city's urban green infrastructure, making it suitable for assessing how the selection of tree species can affect human health, well-being, and overall quality of life in a densely populated urban neighbourhood. Climatic data from the Republic of Serbia's Hydrometeorological Service indicate an average annual temperature of 12.2°C, with August as the warmest month (average 16.1°C minimum, 29.2°C maximum) and January as the coldest (average -2.5°C minimum, 4.3°C maximum). The mean annual precipitation over the 30-year period (1995-2024) is 675.8 mm. Soils within the street profiles are classified as urbisol (OBRKNEŽEV ET AL., 2009).

The approximate areas of the research site sections were measured using the "Measure distance and area" tool in Google Earth (Fig. 2). UGI data were collected along the following streets, with their corresponding areas as follows: Rumenačka (0.91 ha), Hadži Ruvimova and Braće Popović (1.1 ha), Veselina Masleše (1.61 ha), Kornelija Stankovića (0.87 ha), Čika Stevina (0.37 ha), Joakima Vujića (0.25 ha), Pasterova (1.02 ha), Stevana Mokranjca (0.47 ha), Ilije Birčanina (1.12 ha), Dr Svetislava Kasapinovića and Trg Majke Jevrosime (1.0 ha), Janka Čmelika (1.15 ha), Janka Veselinovića (1.71 ha), Koste Racina (0.86 ha) and Cankareva (0.64 ha).

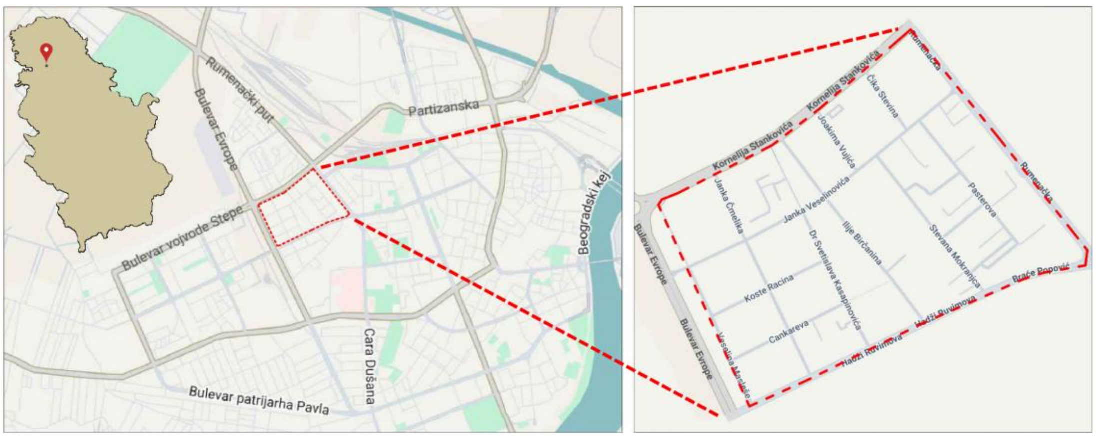

Fig. 1. Location of the study area (Source: Snazzy Maps, 2014; modified by authors)

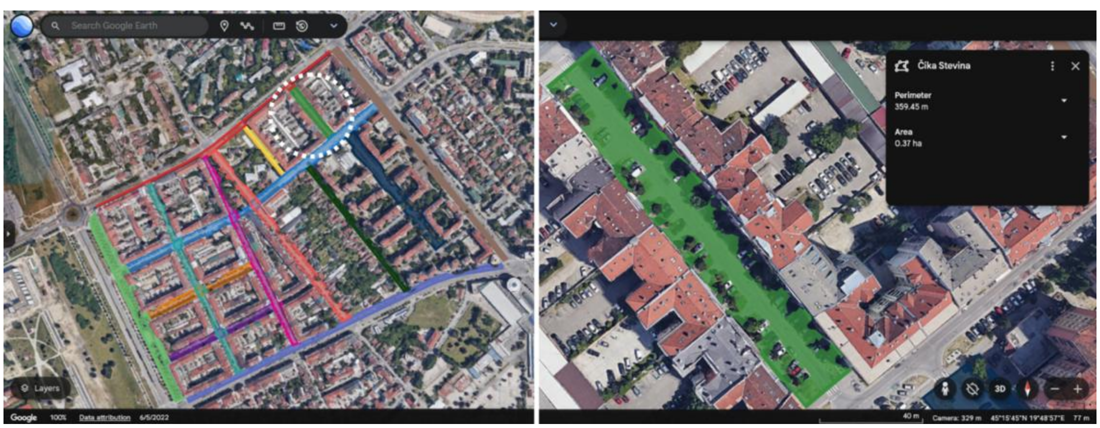

Fig. 2. Measured area of the research site within the street.Each street is represented by a different colour: ■ Kornelija Stankovića, ■ Rumenačka, ■ Čika Stevina, ■ Pasterova, ■ Joakima Vujića, ■ Stevana Mokranjca, ■ Ilije Birčanina, ■ Dr Svetislava Kasapinovića and Trg Majke Jevrosime, ■ Janka Čmelika, ■ Veselina Masleše, ■ Janka Veselinovića, ■ Koste Racina, ■ Cankareva, ■ Hadži Ruvimova and Braće Popović (Source: Google Earth; modified by authors)

2.2. Data collection and statistical analysis

Data on tree species within avenues were collected through a field inventory conducted during April 2025. Species identification was performed using the relevant literature (VUKIĆEVIĆ, 1987; ŠILIĆ, 1990a; 1990b; JOVANOVIĆ, 2008; CVJETĆANIN ET AL., 2016). For each tree, the following basic morphometric parameters were recorded: tree height [m], trunk height [m], and crown diameter [m]. Based on these data, the average crown height for each species (Hi) and the average crown projection area (calculated from the minimum and maximum crown radius on the ground using the ellipse area formula) were determined. The area covered by a given species (Si) was calculated by multiplying the average crown projection area by the number of individuals of that species (ni) within a given street. The values of allergenic potential (ap) and potential allergenic value (VPA) for all identified species were obtained from the literature (CARIÑANOS ET AL., 2014; CARIÑANOS & MARINANGELI, 2021; DE WEGER ET AL., 2024). These data were further used to calculate the Index of Allergenicity of Urban Green Zones ($\mathrm{I_{UGZA}}$) for each street, following the methodology of CARIÑANOS ET AL. (2014) and CARIÑANOS ET AL. (2017). $\mathrm{I_{UGZA}}$ was calculated as follows:

$$\mathrm{I_{UGZA}} = \frac{1}{maxVPA \times S_T} \sum_{i=1}^{k} VPA_i \times Si \times Hi$$

Where:
S_T – Surface area of the street;
k – Number of different species within the street;
VPA_i – Potential Allergenicity Value of the species *i*;
S_i –Surface area occupied by species *i* within the street;
H_i – Average height of species *i* measured within the street;
maxVPA – maximum *VPA* value is 36 (*max*ap=4, *max*pe=3, *max*ppp=3; 4×3×3=36).

Based on the obtained results, the analyzed streets were classified according to their allergenic risk level, following the methodology of CARIÑANOS ET AL. (2019), as:

- Low-risk streets ($\mathrm{I_{UGZA}} < 0.2$);
- Moderate-risk streets ($\mathrm{I_{UGZA}} = 0.2 - 0.3$);
- High-risk streets ($\mathrm{I_{UGZA}} > 0.3$).

Descriptive statistics were used to present the number of individuals according to their allergenic potential in each street, as well as their spatial distribution among streets. The data were presented in tables, box plots, bar charts, and a heat map, providing a detailed overview of variations in the presence of species with different allergenic potentials among the analyzed streets.

Values of the $\mathrm{I_{UGZA}}$ index were calculated for each street to assess the overall level of allergenicity and classify streets according to their allergenic risk level. In addition, a hierarchical cluster analysis was conducted to group streets according to similarities in allergenic potential, considering both the $\mathrm{I_{UGZA}}$ index values and the percentage of highly allergenic trees (ap ≥ 3). The results were presented as a dendrogram, identifying groups of streets with similar allergenicity risk levels. All data processing and graphical visualization were conducted using Microsoft Office Excel 2007 (MICROSOFT CORPORATION, USA, 2007) and Statistica 14.0.0.15 (TIBCO SOFTWARE INC., USA, 2020).

3. Results

Based on the field inventory, a total of 849 individuals belonging to 39 different tree species were recorded throughout the UGI of the study area. Among the analyzed species, the most abundant were *Liquidambar styraciflua* L. (138 individuals), *Corylus colurna* L. (128 individuals), *Celtis australis* L. (99 individuals), *Ulmus pumila* L. (69 individuals), *Quercus robur* 'Fastigiata' (59 individuals) and *Fraxinus excelsior* L. (52 individuals), collectively representing over 60% of the total number of individuals. In contrast, 23 species included fewer than ten individuals, eight of which were represented by only a single individual (Fig. 3).

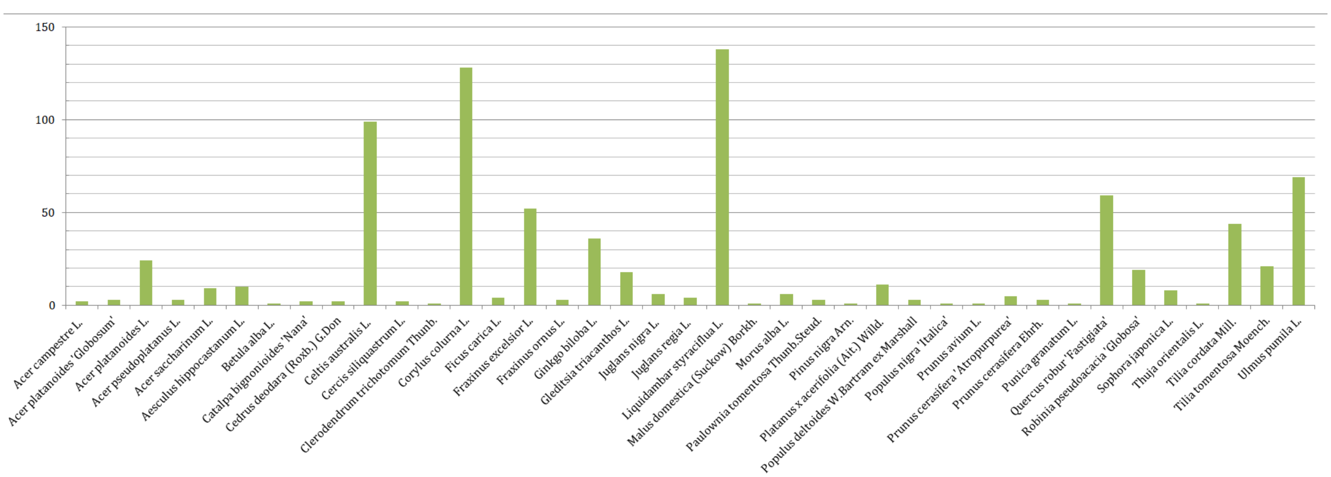

Fig. 3. Species distribution throughout the UGI of the study area

Analysis of the allergenic potential (ap) of the identified species showed that the greater share of species (41%, Table 1) belonged to the low allergenic potential category (ap = 1), while 31% were classified as moderate (ap = 2). The remaining species were classified in higher categories (ap ≥ 3), with only one species exhibiting very low allergenic potential (ap = 0, Table 1). However, when considering the number of individuals in the observed UGI, trees with moderate allergenic potential were the most abundant, with 48% of all trees identified as moderately allergenic. This was followed by individuals with high (31%) and low allergenic potential (15%), while trees with very high allergenic potential accounted for 6% of the total. Very low allergenic potential, occurred in only one individual (Table 1).

Table 1. Allergenic potential (ap) of species and individuals identified in UGI of the study area. Allergenic potential values: 0 – very low ap ; 1 – low ap; 2 – moderate ap; 3 – high ap; 4 – very high ap

Allergenic potential (ap)	Number of species	% of species	Number of individuals	% of individuals
0	1	3	1	0
1	16	41	126	15
2	12	31	405	48
3	8	21	264	31
4	2	5	53	6
Total	39	100	849	100

Within the species with moderate allergenic potential (ap = 2), the widest range of individuals per species was observed. A similar pattern of variability, although of lower intensity, was also recorded among species with high allergenic potential (ap = 3). Species with low allergenic potential (ap = 1) were generally represented by a small number of individuals, with the exception of one species that markedly exceeded others in abundance. The least variation was observed in species with very low (ap = 0) and very high (ap = 4) allergenic potential, where all species were represented by a small number of individuals and without notable deviations in abundance (Fig. 4). This distribution further indicates that the majority of trees are species with moderate and high allergenic potential, although the number of individuals within these categories varies considerably among species.

Marked differences in UGIs were observed in the distribution of trees by allergenic potential among streets (Fig. 5). The observed UGI in streets Čika Stevina, Kornelija Stankovića, and Rumenačka feature only trees with high or moderate allergenic potential (ap = 3 or 2), with no presence of other categories. In contrast, the UGI in streets Ilije Birčanina, Koste Racina and Janka Čmelika include trees of (almost) all allergenic potential levels, indicating greater diversity within the analyzed categories.

These differences are further emphasized through a heat map (Fig. 6), which provides a visual representation of the number of trees categorized by their allergenic potential in the UGIs of each street. Darker fields indicate a higher number of trees within a given allergenic potential category, while lighter fields represent lower abundance or complete absence. As visible in the heat map, trees with moderate allergenic potential (ap = 2) are most numerous across the UGIs of the whole study area, particularly in UGI of streets such as Veselina Masleše, Janka Čmelika, Kornelija Stankovića and Rumenačka. Higher allergenic potential categories (ap ≥ 3) prevail in the UGIs of Cankareva, Čika Stevina, Dr Svetislava Kasapinovića and Trg Majke Jevrosime. Conversely, trees with lower allergenic potential (ap ≤ 1) are generally scarce and unevenly distributed across the street UGIs.

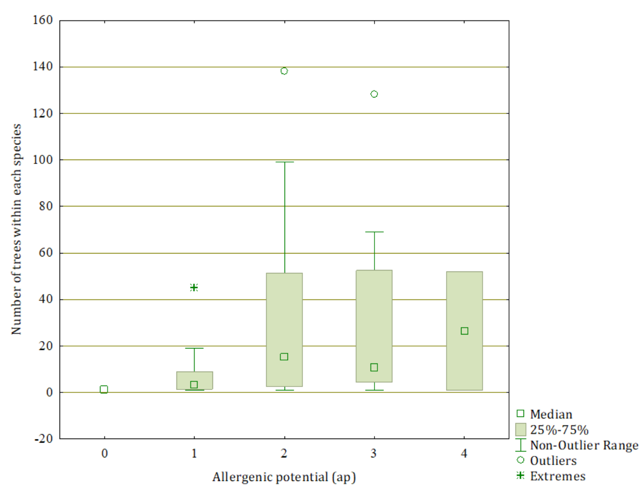

Fig. 4. Box plot of the number of trees per species by allergenic potential. Allergenic potential (ap) values: 0 – very low ap ; 1 – low ap; 2 – moderate ap; 3 – high ap; 4 – very high ap

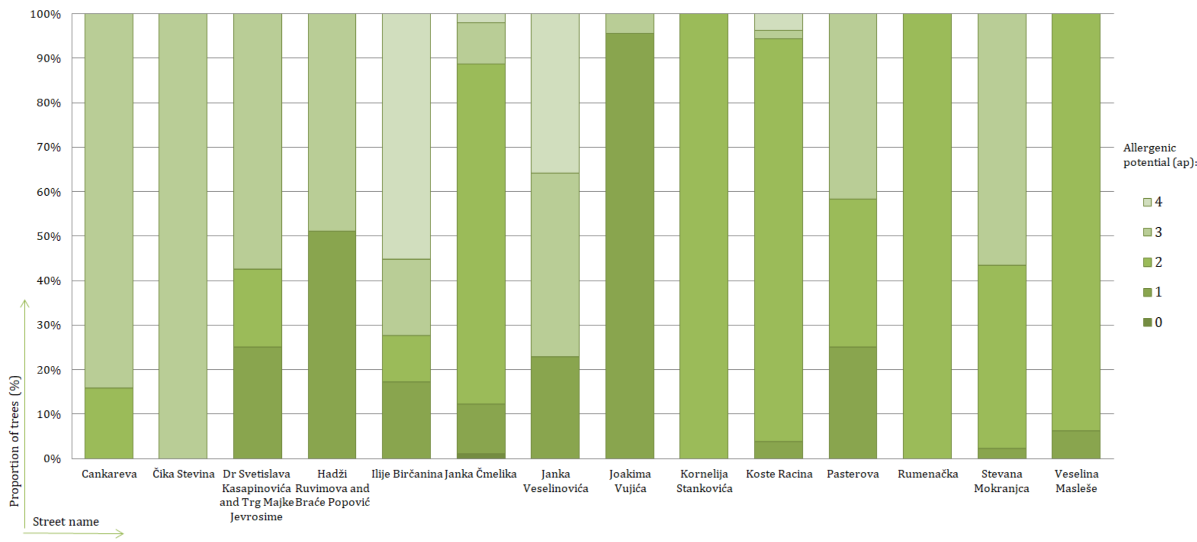

Fig. 5. Distribution of allergenic potential of trees across the analyzed streets. Allergenic potential (ap) values: : 0 – very low ap ; 1 – low ap; 2 – moderate ap; 3 – high ap; 4 – very high ap

Street name	Allergenic potental (ap) 0	1	2	3	4
Cankareva	0	0	9	48	0
Čika Stevina	0	0	0	43	0
Dr Svetislava Kasapinovića and Trg Majke Jevrosime	0	20	14	46	0
Hadži Ruvimova and Braće Popović	0	23	0	22	0
Ilije Birčanina	0	5	3	5	16
Janka Čmelika	1	11	75	9	2
Janka Veselinovića	0	21	0	38	33
Joakima Vujića	0	22	0	1	0
Kornelija Stankovića	0	0	69	0	0
Koste Racina	0	2	48	1	2
Pasterova	0	15	20	25	0
Rumenačka	0	0	57	0	0
Stevana Mokranjca	0	1	19	26	0
Veselina Masleše	0	6	91	0	0

Number of trees

Fig. 6. Heat map of the number of trees with different allergenic potential in the analyzed streets. Darker fields indicate a greater number of trees within a given allergenic potential category, while lighter fields represent fewer trees or an absence. Allergenic potential (ap) values: : 0 – very low ap ; 1 – low ap; 2 – moderate ap; 3 – high ap; 4 – very high ap

Assessing the allergenic potential of the recorded species offers a preliminary understanding of the potential risk they may pose in an urban environment, without considering the spatial distribution, abundance, height, canopy area, or the combined effect of these factors. To obtain a more comprehensive assessment of the residents' exposure to allergens and the contribution of individual trees to the overall allergenic impact, the Index of Allergenicity of Urban Green Zones (I_{UGZA}) was applied, which integrates all relevant factors into a single numerical value.

The IUGZA index reveals distinct differences in allergenic potential among the analyzed UGIs of the observed streets (Fig. 7). The highest value of this index was recorded in Stevana Mokranjca Street (0.37), which, according to the categorization by CARIÑANOS ET AL. (2019), places this street in the high-risk category ($I_{UGZA} > 0.3$). All other streets fall into the low-risk category ($I_{UGZA} < 0.2$), although noticeable differences in the intensity of allergenicity exist among them. The UGI in these streets: Pasterova Street (0.16), as well as Cankareva, Hadži Ruvimova and Braće Popovića streets (0.15), stand out for higher values of the I_{UGZA} index within the low-risk category ($I_{UGZA} < 0.2$). In contrast, the I_{UGZA} index values of UGIs in Joakima Vujića (0.02) and Kornelija

Stankovića streets (0.01) are significantly lower, with nearly negligible values. This variability within the same risk category further emphasizes the importance of a quantitative approach in risk assessment, rather than relying solely on the presence of species with high allergenic potential.

A detailed overview of the UGI data for the researched streets, covering area, number of individual trees, biometric characteristics, and allergenic potential, along with the calculated I_{UGZA} index values, is presented in Table 2 in the supplementary material. This provides a more accurate assessment of the contribution of the individual factors to the overall I_{UGZA} index value.

The clustering results (Fig. 8) reveal distinct grouping patterns, where streets with similar vegetation structures and comparable shares of highly allergenic species (ap ≥ 3) are clustered together. Streets that are linked by shorter branch lengths exhibit a higher degree of similarity, suggesting common characteristics in terms of both allergenic potential and overall greenery composition. Two broader clusters can be distinguished. The first encompasses streets that show lower differentiation in allergenic load, indicating relatively balanced vegetation with moderate to low shares of species with high allergenic potential. In contrast, the second cluster groups streets characterized by higher variability and often greater dominance of allergenic species, which directly influences the I_{UGZA} index values. This classification highlights spatial patterns in allergenic risk and emphasizes that certain streets share common ecological profiles, while others stand out due to a more pronounced presence of highly allergenic species. Such differentiation is valuable for urban greenery planning, as it points to areas where interventions may be needed to mitigate allergenic exposure for the local population.

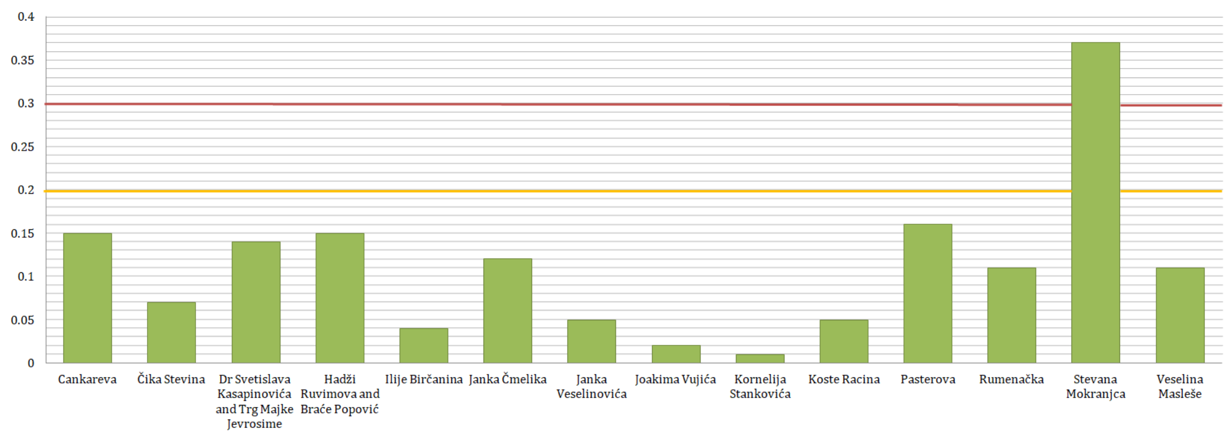

Fig. 7. Values of I_{UGZA} indices within the UGIs of analyzed streets. The red and yellow lines indicate the threshold of the I_{UGZA} indices for high (I_{UGZA} > 0.3) and moderate (I_{UGZA} = 0.2 - 0.3) risk, respectively, based on Cariñanos et al. (2019)

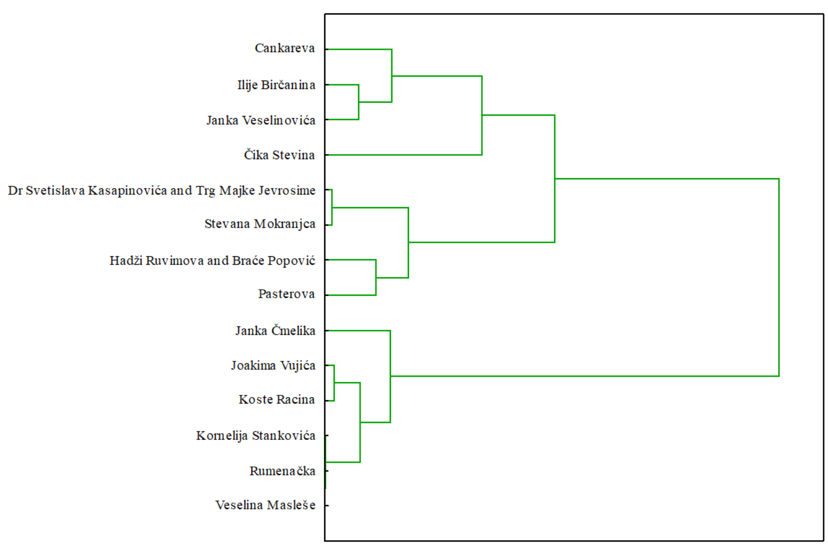

Fig. 8. Diagram of the hierarchical cluster analysis of the analyzed streets based on I_{UGZA} index values and the proportion of highly allergenic species (ap ≥ 3)

4. Discussion

Tree avenues represent an important part of urban green infrastructure due to the numerous functional and ecosystem benefits they provide to residents of urban areas. For this reason, species selection when planting this type of greenery should be carried out carefully and based on defined characteristics (Dobrilovič, 2009), with species allergenicity considered as an important criterion (Cariñanos et al., 2019; Cariñanos & Marinangeli, 2021; De Weger et al., 2024). However, planning and management of tree avenues require a careful balance between reducing allergenic exposure (Cariñanos et al., 2014; Cariñanos et al., 2017) and preserving essential ecosystem services provided by urban trees (Dobrilovič, 2009; Osseni, 2021; Aravindhan et al., 2024), such as microclimate regulation (Gromke & Blocken, 2015; Hong et al., 2017) and mitigation of traffic-related air pollution (Gromke & Blocken, 2015; Aravindhan et al., 2024; Kalozi et al., 2025). In this context, emphasis is placed on strategic diversification of tree species that maintain ecosystem functionality while reducing the overall pollen load, carefully avoiding unintended risks such as overemphasis on the removal of existing trees.

In this study, differences were observed in the presence of allergenic tree species within the UGI of the analyzed streets. Across the UGI of the entire study area, individuals with moderate allergenic potential (ap =2) were the most prevalent, while the smallest share belonged to trees with very low allergenic potential (ap = 0). A considerable proportion of highly allergenic (ap ≥ 3) and low-allergenic (ap = 1) trees was also recorded. This distribution can be considered acceptable, as species with moderate allergenic potential do not pose a high risk to the health of the majority of the population. However, analyzing the results solely at the level of the entire UGI area may obscure existing differences in the distribution of allergenic trees among UGIs of different streets.

As noted, the distribution of individual trees among allergenic potential categories varies considerably from street to street. Among the 14 analyzed streets, the UGI of Rumenačka and Kornelija Stankovića streets included only species with moderate allergenic potential (ap = 2), while the UGI of Čika Stevina Street included exclusively species with high allergenic potential (ap = 3). In the UGI of Janka Čmelika Street, all allergenic potential categories were represented. Two allergenic potential categories were recorded in the UGI of Cankareva, Hadži Ruvimova and Braće Popović, Joakima Vujića, and Veselina Masleše streets, three categories in the UGI of Janka Veselinovića, Dr Svetislava Kasapinovića and Trg Majke Jevrosime, while the remaining streets included four categories of allergenic potential within their UGIs. In this context, the presence of several allergenic potential categories within the UGI of a single street can be regarded as a positive indicator, particularly when the number of tree individuals with high allergenic potential is relatively small. In such cases, category diversity helps to reduce the overall health risk to the population (Cariñanos et al., 2014), as the effect of a small number of highly allergenic trees is mitigated by the heterogeneous structure of the avenue. On the other hand, UGIs that included only species with moderate allergenic potential, such as those of Rumenačka and Kornelija Stankovića streets, also represent favourable structural examples, since the homogeneous presence of moderately allergenic species considerably reduces the risk of allergenic reactions among users of these spaces.

Values of the I_{UGZA} indices indicate pronounced differences in allergenic potential among the analyzed UGIs of the streets, further emphasizing the importance of including quantitative parameters into the risk assessment, such as the number of individuals, the area occupied by allergenic species (Cariñanos et al., 2014; Cariñanos et al., 2017; Cariñanos et al., 2019), as well as the analyzed area within the street. The highest value of this index was recorded in the UGI of Stevana Mokranjca Street (0.37), which was thus classified as a street of high allergenic risk (Cariñanos et al., 2019). The increased value is mainly due to the predominance of *Ulmus pumila* L., a species with a very high potential allergenic value (VPA = 12; Table 2, Supplementary material). Moreover, as the tree avenue extends along only one side of the street, the analyzed UGI area is relatively small (0.47 ha). This result indicates that even a relatively small green space can exhibit a pronounced allergenic potential if it is dominated exclusively by highly allergenic species.

Conversely, streets such as Cankareva, Janka Veselinovića, Dr Svetislava Kasapinovića and Trg Majke Jevrosime include a greater number of highly allergenic species in their UGIs, but also larger analyzed UGI areas, which results in lower I_{UGZA} index values. The UGI of Čika Stevina Street also includes highly allergenic species; however, their potential allergenic values are lower (VPA = 4; Table 2, Supplementary material). Therefore, despite the smaller size of the analyzed UGI area (0.37 ha), the I_{UGZA} index value remains lower. These findings highlight the importance of integrating all parameters that contribute to the determination of potential allergenic value, as allergenic potential alone is inadequate for an accurate risk assessment. It is also essential to consider the size of the analyzed area, as a realistic assessment of allergenic risk can only be achieved by taking all relevant factors into account, with the I_{UGZA} index providing the final measure of overall allergenic risk (CARIÑANOS ET AL., 2019).

Within the low-risk classified streets, the UGI of Pasterova Street stands out with an I_{UGZA} index value of 0.16, representing the highest value within this category. Together with the UGIs of Cankareva, Hadži Ruvimova and Braće Popovića streets (I_{UGZA} = 0.15), these streets show that, due to the future development of the existing tree individuals or their potential replacement with other species, they may transition into a higher allergenic risk category (moderate-risk streets, $I_{UGZA} = 0{,}2 - 0{,}3$). In this context, planning future plantings is essential in order to manage potential increases in allergenic risk. In contrast, UGIs of Joakima Vujića (I_{UGZA} = 0.02) and Kornelija Stankovića streets (I_{UGZA} = 0.01) emerge as the most favourable streets in terms of allergenic risk. Their exceptionally low I_{UGZA} index values result from the presence of only a single species (with the exception of one tree of *Morus alba* L. in the UGI of Joakima Vujića Street) characterized by low allergenic potential. Accordingly, given the current structure of the tree avenues and morphometric parameters of the trees, no significant increase in the index value is expected.

The application of the I_{UGZA} index as a tool for ecological analysis (CARIÑANOS ET AL., 2017) of tree avenues in the streets of the Nova Detelinara district enabled the assessment of the spatial distribution of allergenic risk within the urban environment, the recognition of a street's UGIs with potentially high-risk species, and the evaluation of the current level of residents' exposure to pollen allergies (CARIÑANOS ET AL., 2017; CARIÑANOS & MARINANGELI, 2021; CALATAYUD & CARIÑANOS, 2024). Beyond providing an overview of the current situation, the application of the I_{UGZA} index can also serve as a useful tool for planning future interventions (CARIÑANOS ET AL., 2017; CARIÑANOS ET AL., 2019) within the analyzed UGIs of the streets. The study area represents a typical residential zone of medium population density, dominated by apartment buildings. In such an urban setting, it is particularly important to carefully select plant species and plan their spatial arrangement, given the proximity of tree canopies to residential buildings and the increased exposure of the residents to allergens (NOWAK & OGREN, 2021). Nevertheless, a more comprehensive assessment of allergenic risk would benefit from future research incorporating surveys among residents to better understand the actual health impacts associated with different levels of allergen exposure across streets. By integrating perception- and health-based data with I_{UGZA} index results, allergenicity assessment for UGI planning could be further strengthened. This need becomes even more pronounced considering the presence of educational institutions in the analyzed area and the planned construction of additional schools and a kindergarten. Children, as a particularly vulnerable population due to extended outdoor activity and increased respiratory sensitivity, require special attention in the planning of a safe green environment (LAALA ET AL., 2025). In this context, the I_{UGZA} index not only allows the identification of existing risk zones, but also provides a basis for long-term, scientifically based decisions, including the selection of low-allergenic species, the spatial arrangement of plantings, and the implementation of corrective measures where necessary (CARIÑANOS ET AL., 2014; CALATAYUD & CARIÑANOS, 2024). At the same time, allergenic risk in such sensitive urban settings may be further intensified by broader urban environmental factors, including anthropogenic heat emissions associated with the urban heat island effect. Such emissions can modify the local urban microclimate by increasing air temperatures, which may prolong pollen seasons, enhance pollen production, and promote the formation and dispersion of air pollutants. These combined effects can intensify allergen exposure and contribute to an increased risk of respiratory allergic symptoms (NIU ET AL., 2025). To fully understand the health implications, it is necessary to consider the interactions between environmental factors and the allergenic properties, including potential cross-reactivity of tree species. Further research integrating local pollen composition, species distribution, and environmental stressors could help identify additional allergen sources and clarify their combined effect on residents' health.

Since the research focused exclusively on tree avenues, the obtained results do not fully reflect the overall allergenic risk within the Nova Deteilinara district. Therefore, it is important that future studies include additional forms of urban greenery, as well as factors such as air pollution and street ventilation, which together would provide a more accurate assessment of residents' exposure to allergens. In this way, all elements of green infrastructure would be covered, allowing a more comprehensive and accurate assessment of allergenic risk in this part of the city. The results of such analyses can serve as a basis for developing local guides on tree pollen allergenicity, adapted to the specific conditions of the urban environment, thereby improving green space management in the context of public health. In this regard, the study is applicable at the city level, serving as a decision-support tool for authorities and contributing to the development of a healthier UGI.

5. Conclusions

The research results indicate pronounced differences in the presence of allergenic tree species within the analyzed UGIs of the streets, with most individuals classified into categories of moderate and high allergenic potential. Although certain streets exhibit a higher proportion of highly allergenic tree individuals within their UGIs, these are generally accompanied by other individuals with varying levels of allergenic potential, which helps reduce the overall health risk for the local population. According to the I_{UGZA} index, all analyzed streets fall into the low allergenic risk category, except for the Stevana Mokranjca Street, which is classified as high risk due to the predominance of tree individuals with very high potential allergenic value. This study provides a comprehensive representation of the allergenic risk status within the observed UGIs. The obtained results offer a scientific basis for planning and improving green spaces in the context of public health. Ultimately, integrating an allergenic risk assessment into urban greenery planning can help create healthier and more resilient urban environments. Such an approach not only supports public health protection but also contributes to the sustainable development of urban green infrastructure. Further research on this subject, combined with the incorporation of such knowledge into urban greenery practices, will be essential for advancing strategies that mitigate allergenic risks while maximizing the ecological, social, and health benefits of urban green spaces.

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Supplementary material

Table 2. Overview of I_{UGZA} index values and parameters included in its calculation by streets within the Nova Detelinara city district

List of species within **streets**	Measured area of the research site within the street in ha	Potential Allergenicity Value for each species (VPA) by Cariñanos et al., 2014; Cariñanos and Marinangeli, 2021; De Weger et al., 2024	No. of Individuals in the street	Surface area occupied by each species in m²	Average tree height of species in m	Contribution of each represented species to I_{UGZA}	Overall I_{UGZA} index of the street
Cankareva	**0.64**						**0.15**
Corylus colurna L.		4	47	922.84	7.2	0.1154	
Quercus robur 'Fastigiata'		2	6	71.68	5.9	0.0037	
Tilia tomentosa Moench.		4	3	27.24	3.8	0.0018	
Ulmus pumila L.		12	1	58.09	9.2	0.0278	
Čika Stevina	**0.37**						**0.07**
Corylus colurna L.		4	42	581.89	4.2	0.0734	
Ulmus pumila L.		12	1	3.80	4.2	0.0014	
Dr Svetislava Kasapinovića and Trg Majke Jevrosime	**1.00**						**0.14**
Ginkgo biloba L.		12	36	522.79	4.3	0.0749	
Gleditsia triacanthos L.		4	18	325.72	8.2	0.0297	
Liquidambar styraciflua L.		2	5	22.62	1.6	0.0002	
Malus domestica (Suckow) Borkh.		1	1	4.15	1.5	0.00002	
Pinus nigra Arn.		2	1	33.18	11	0.0020	
Platanus x acerifolia (Ait.) Willd.		3	3	199.43	11	0.0183	
Prunus cerasifera Ehrh.		1	1	1.33	1.3	0.000005	
Tilia cordata Mill.		4	1	26.42	5.8	0.0017	
Tilia tomentosa Moench.		4	7	197.92	7.1	0.0156	
Ulmus pumila L.		12	7	17.81	2.2	0.0013	
Hadži Ruvimova and Braće Popović	**1.10**						**0.15**
Liriodendron tulipifera L.		1	23	260.85	6	0.0040	
Ulmus pumila L.		12	22	664.20	7.2	0.1449	
Ilije Birčanina	**1.12**						**0.04**

Betula alba L.		18	1	0.13	0.7	0.000004	
Cedrus deodara (Roxb.) G.Don		18	2	16.08	3.2	0.0023	
Fraxinus excelsior L.		18	15	170.12	3.4	0.0258	
Fraxinus ornus L.		18	3	15.93	2	0.0014	
Prunus cerasifera 'Atropurpurea'		1	5	318.09	6.6	0.0052	
Tilia tomentosa Moench.		4	1	32.17	6.6	0.0014	
Ulmus pumila L.		12	2	49.26	3.9	0.0057	
Janka Čmelika	**1.15**						**0.12**
Acer campestre L.		2	2	16.08	4.2	0.0003	
Acer pseudoplatanus L.		2	1	7.07	3.8	0.0001	
Catalpa bignonioides 'Nana'		1	2	3.08	0.8	0.00001	
Clerodendrum trichotomum Thunb.		0*	1	2.01	1	0.0000	
Ficus carica L.		0	3	7.63	1.6	0.0000	
Fraxinus excelsior L.		18	2	7.60	2.8	0.0009	
Juglans nigra L.		18	3	1.91	1	0.0001	
Liquidambar styraciflua L.		2	64	1359.18	5.2	0.0341	
Morus alba L.		18	3	90.57	6.4	0.0252	
Populus deltoides W.Bartram ex Marshall		18	3	73.89	10.3	0.0331	
Populus nigra 'Italica'		18	1	28.27	17.5	0.0215	
Prunus avium L.		1	1	6.16	2.6	0.00004	
Prunus cerasifera Ehrh.		1	1	32.17	3.6	0.0003	
Punica granatum L.		0	1	2.54	0.9	0.0000	
Quercus robur 'Fastigiata'		2	6	36.95	5.7	0.0010	
Tilia tomentosa Moench.		4	2	30.41	3.15	0.0009	
Ulmus pumila L.		12	2	36.19	4.4	0.0046	
Janka Veselinovića	**1.71**						**0.05**
Corylus colurna L.		4	27	245.14	4.3	0.0068	
Ficus carica L.		0	1	1.13	1.2	0.0000	
Fraxinus excelsior L.		18	33	299.61	4.2	0.0368	
Juglans nigra L.		18	3	24.13	4.2	0.0030	

Morus alba L.		18	1	24.63	4.9	0.0035	
Prunus cerasifera Ehrh.		1	1	1.54	1.7	0.000004	
Robinia pseudoacacia 'Globosa'		4	19	78.94	1.4	0.0007	
Ulmus pumila L.		12	7	87.96	2.4	0.0041	
Joakima Vujića	**0.25**						**0.02**
Liriodendron tulipifera L.		1	22	135.47	6.5	0.0098	
Morus alba L.		18	1	6.16	6.3	0.0078	
Kornelija Stankovića	**0.87**						**0.01**
Liquidambar styraciflua L.		2	69	262.29	3	0.0050	
Koste Racina	**0.68**						**0.05**
Fraxinus excelsior L.		18	2	16.08	3.5	0.0041	
Morus alba L.		18	1	10.18	3.1	0.0023	
Quercus robur 'Fastigiata'		2	47	850.49	5.9	0.0410	
Sophora japonica L.		1	2	5.09	1.9	0.00004	
Tilia tomentosa Moench.		4	1	11.95	6.9	0.0013	
Pasterova	**1.02**						**0.16**
Acer platanoides L.		3	6	181.14	8.1	0.0120	
Acer pseudoplatanus L.		2	2	2.26	1.4	0.00002	
Acer saccharinum L.		2	2	60.38	9.8	0.0032	
Aesculus hippocastanum L.		8	10	5.03	1.2	0.0001	
Cercis siliquastrum L.		2	2	52.84	4.1	0.0012	
Corylus colurna L.		4	12	235.62	4.3	0.0110	
Juglans nigra L.		18	4	105.68	4.4	0.0228	
Platanus x acerifolia (Ait.) Willd.		3	8	760.27	12.2	0.0758	
Sophora japonica L.		1	3	150.80	7.8	0.0032	
Tilia cordata Mill.		4	9	271.72	7.3	0.0216	
Tilia tomentosa Moench.		4	1	27.34	7.3	0.0022	
Ulmus pumila L.		12	1	18.86	5.8	0.0036	
Rumenačka	**0.91**						**0.11**
Acer saccharinum L.		2	6	301.59	8.4	0.0155	

Celtis australis L.		8	16	232.35	3.9	0.0221	
Tilia cordata Mill.		4	34	898.31	6.2	0.0680	
Tilia tomentosa Moench.		4	1	34.21	6.4	0.0027	
Stevana Mokranjca	**0.47**						**0.37**
Acer platanoides L.		3	18	299.14	6.2	0.0329	
Acer saccharinum L.		2	1	63.62	12.7	0.0096	
Thuja orientalis L.		1	1	19.63	7.3	0.0008	
Ulmus pumila L.		12	26	889.51	5.2	0.3280	
Veselina Masleše	**1.61**						**0.11**
Acer platanoides 'Globosum'		3	3	24.13	1.4	0.0002	
Celtis australis L.		8	83	1762.68	4.3	0.1046	
Paulownia tomentosa Thunb.Steud.		2	3	58.90	4.7	0.0010	
Sophora japonica L.		1	3	18.47	1.4	0.0000	
Tilia tomentosa Moench.		4	5	62.83	5	0.0022	

*The VPA value for *Clerodendrum trichotomum* Thunb. was not explicitly reported in the literature; rather, it was derived by the authors through interpretation of data on this species from Li et al. (2025).