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Effectiveness of Legislative Measures in Protecting Trees as Key Elements of Green Infrastructure

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Abstract

The concept of green infrastructure is becoming increasingly central to both national and international research, particularly for its role in promoting ecological stability, protecting biodiversity, and supporting multifunctional land use and landscape diversity. In cultural landscapes, elements such as solitary trees, tree groups, and tree rows are integral components of green infrastructure, fulfilling essential ecological, aesthetic, cultural-historical, and landscape functions. Among these, protected trees are a critical element, serving as key indicators in comprehensive landscape-ecological assessments of urban environments. This paper aims to (i) evaluate the distribution and number of protected trees in Bratislava, the capital of Slovakia, and (ii) assess whether these trees meet the established criteria for protection. Additionally, we examined factors within the protection zones of these trees that may negatively impact their occurrence, vitality, and stability. The results are presented through graphical analysis and photographic documentation. Furthermore, the study includes findings from a sociological survey conducted via an online questionnaire with a sample of 514 respondents, highlighting the perceived importance of these trees in the urban environment.

Keywords: *Green Infrastructure, Urban Environment, Cultural Heritage, Sociological Survey, Bratislava.*

Introduction

Green infrastructure (GI) is a fundamental tool for ensuring the spatial stability of the landscape. It is part of the policies of individual EU Member States, including Slovakia. It can be found in a number of important documents and strategies of the European Union. In Slovakia, the issue of green infrastructure is addressed in long-term development strategies such as the *Strategy of Economic Policy of the Slovak Republic until 2030, Greener Slovakia - Strategy of Environmental Policy of the Slovak Republic until 2030, Strategy of Adaptation of the Slovak Republic to Climate Change, Draft Vision* and *Strategy of Development of Slovakia until 2030 - Long-term Strategy of Sustainable Development of the Slovak Republic - Slovakia* 2030, etc. Green infrastructure is also part of Slovak legislation. It is enshrined in Act No 543/2002 Coll. on Nature and Landscape Protection as amended, which defines it as a network of natural and semi-natural elements, primarily green areas and aquatic ecosystems, which is created and managed to provide a wide range of ecosystem services, with particular regard to ensuring biodiversity, ecological stability and a favourable environment. The concept of green infrastructure in Slovakia is linked to the concept of ecological networks NECONET, EECONET, NATURA 2000 and the Territorial system of ecological stability (TSES), which ensure the ecological stability of the landscape.

Ecological stability is a topic of research for many domestic and foreign authors, e.g. Marks et al. (1989), Niemann (1988), Haber (1979) Forman & Godron (1986), Naveh & Liebermann (1994), Míchal (1992) and Tremboš et al. (1999). Its increase is also dealt with by Buček (2012), Maděra (2010), Buček & Lacina (1993), who focus their research on examining the spatial parameters of ecological networks. These authors understand the ecological network as a system of ecologically significant landscape segments, which are the basis of the TSES. From the landscape ecological point of view, the definition of Ružička & Miklós (1982) is closest to our research. They understand ecological stability as the dynamic ability of the landscape structure to maintain spatial ecological relationships between geosystems, as well as the ability to maintain

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and restore the system's functioning conditions and ensure ecological diversity in the entire spectrum of the landscape structure, even if this structure is made up of less stable, unstable, or inert elements.

Ecological stability in the cultural landscape is also enhanced by point elements of green infrastructure such as trees, groups of trees, tree alleys, etc. They fulfil many important functions that increase the landscape and aesthetic value of the area, especially in urbanized environments (Mansoor and Paul, 2022). Here they improve microclimatic conditions, increase humidity, reduce dust, temperature and pollutant content, and are the habitat for several species of birds, butterflies, beetles and other groups of insects. For this reason, trees are an important part of green infrastructure that increases ecological stability, biodiversity and the overall quality of the environment. A special status corresponds to protected trees, which are characterized by high cultural, scientific, ecological, landscape or aesthetic value. Tree protection in Slovakia has a rich history. It has been mentioned already in the State Nature Protection Acts No. 1/1955 and No. 287/2004. It is currently enshrined in Act No 543/2002 Coll. on Nature and Landscape Protection, as amended.

The evaluation of point elements of green infrastructure in urbanized landscapes is dealt with by Šerá (2013), Bouček (1991) and Slovak garden and landscape architects, such as Supuka (1998), Supuka, Bihúňová & Štepánková (2005), Rózová (1993,1999), Hudeková (2018). In their works, they address green infrastructure by planting trees, tree plantations and groups of trees in urban environment. Baumannová (2010) discusses ways of expanding green areas in settlements in the form of vegetated roofs, which are a trend in the construction of new urban settlements in Germany, Japan, as well as Austria and Denmark. Research on trees as point elements of green infrastructure has been dealt with for many years by Eliáš (1974, 1985, 2003a, 2003b), who devoted a large part of his research work to the study of protected trees, especially Turkey oaks in the cadaster of the village of Velčice. Baránková (2022) evaluates trees mentioned in folk songs. Juriš & Zahradníková (2022) followed trends in the development of trees in the Medická zahrada public park in Bratislava. Protected trees in the capital city were also assessed by Dolánová & Zahradníková (2022), who focused on the analysis of the health status and the increase in trunk circumference. The economic expression of the cultural value of important trees using a web application is discussed by Pechanec & Machar (2022). The categorization of trees based on cultural and historical significance was developed by Vlčková (2018) and Rudl (2016), who, like Rotherham (2021), view trees as a heritage of national and cultural identity. The management of ancient, historic trees is addressed by Read (2000) and Lonsdale (2013). Respondents' attitudes towards the environmental, spiritual, health, aesthetic and utilitarian functions of trees were assessed by Stachová et al. (2020) through a questionnaire survey. A survey focused on significant trees in Czechia was conducted by Rudl & Machar (2021). Methodological procedures for the care of valuable trees were developed by Shigo (1991), Siewniak & Kusche (2002) and Žďárský et al. (2008). Research on protected trees is dealt with by a number of other authors, landscape ecologists, geographers, conservationists, architects, urban planners, etc., who approach the issue from their professional point of view.

The aim of this paper is (i) to map and evaluate protected trees in the capital of the Slovak Republic, Bratislava and (ii) to analyse the environmental factors that could have negative impact on protected trees and compare these data with those published by the State Nature Conservancy**.** The landscape-ecological research is supplemented with a sociological survey conducted in the form of an online questionnaire. The aim of the questionnaire survey was to obtain the view of the respondents on the issue of green infrastructure and the evaluation of protected and important trees in the capital city.

Material & Methods

In the landscape-ecological part of the research we based on the available data sources of the State Nature Conservancy and supplemented them with the results obtained from the field research - mapping of protected trees in five Bratislava districts. In each city district we mapped the occurrence of protected trees. We focused on the analysis of the location of the trees, the number of individuals and the current condition of the tree. We evaluated, (i) whether they meet the reason for their protection, (ii) the factors acting in the immediate vicinity of the trees in accordance to §49 of Act No. 543/2002 Coll., paragraph 7 and (iii) other factors that may have a negative impact on the health status of trees (assessment of the overall visual aspect

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of the tree and its surroundings - the vitality of the tree and mechanical stability). To assess the vitality and health status of the trees, we relied on the work of Hrubík and Tkáčová (2004). We entered the results in a table, evaluated them graphically and documented them photographically.

The Slovak State Nature Conservancy lists 28 protected trees in the city of Bratislava, of which 22 are deciduous and 6 coniferous. 26 individuals are located in the Old Town District. The remaining two individuals are in Bratislava IV District. (tab. 1). All individuals have a valid protection document listed on the website of the State Nature Conservancy. Prohibited activities in the tree protection zone of protected trees (according to §49 of Act No. 543/2002 Coll., paragraph 7) include:

Driving or standing with a motor vehicle or a sled vehicle off a road, a special purpose road or other paved road.

Establishing access roads for motor vehicles or sled vehicles.

To carry out engineering geological work.

Apply chemicals or fertilizers.

To carry out ground shaping.

Construct fencing on the property.

To place a sheep folds or other shelters for livestock.

Dump waste or store building materials, lumber, or other materials that may cause soil compaction over the root system of a protected tree.

Place informational, advertising, or promotional equipment.

To place a structure/building.

To make or maintain an open fire, produce smoke or discard burning or smouldering objects, handle combustible materials, or burn vegetative cover.

Conduct any activity that interferes with the water regime of a protected tree.

Plant non-native tree species.

Harvest timber applying a clear-cut management method.

Grazing, watering, overgrazing or roosting livestock.

In the sociological part of the research we conducted an online questionnaire survey. We evaluated the respondents' answers in Excel and visualized them graphically. To verify whether there is a statistically significant relationship between gender, age, education and type of residence and respondents' preferences in their answers, we used the Chi-squared test of independence (RStudio Team, 2023).

Results

The field survey of protected trees in Bratislava took place in the summer months of 2022. The online questionnaire was distributed to respondents between October 2 and November 2, 2023. We updated the data from the field survey in 2024.

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Results of Landscape-Ecological Research

The saucer magnolia (*Magnolia x soulangiana*) (236 registration number of the tree in the List of Specially Protected Parts of Nature of the Slovak Republic; fig. 1a). The tree is visually in good health, with no signs of damage of individual parts of the tree. It is located on private land - in the yard without public access. In the immediate vicinity of the tree there is a loose substrate (a circle with a diameter of about 50 cm). Closely behind this part is a gravel area that serves as a parking area for residents' cars. In this area, the prohibition of "driving or standing with a motor or sled vehicle off a road or other paved way" (§49 (7) (a)) is violated in the tree protection zone. The root system of the tree is burdened by the weight of parked cars with the risk of motor oil leakage into the soil. There is a busy Palisády street in the wider vicinity of the tree, so the tree is also at risk of reduced air quality caused by the motor vehicle exhaust fumes.

The black pine (*Pinus nigra*) (reg. no. 489; fig. 1b) is located in a quiet environment in the direction of Barónka city quarter. The tree is in a good state of health, the individual parts of the tree do not show any signs of damage visually. The tree is located in the garden of a private property, without public access. Garden fence, a concrete wall in the immediate vicinity of the trunk placed about 30 cm away from the tree trunk separates the garden from the road. In this case, the prohibition to 'construct a fence on land within the protection zone of a protected tree' (§49 (7) (f)) has been violated. The wires of the power lines above the crown of the tree are also a potential threat to the tree, which may be a reason to cut it down in the future.

The Adriatic oak (*Quercus virgiliana*) (reg. no. 214; fig. 1c) is located in a public open space in a quiet area of the Slavín city quarter. The protected tree is significantly negatively affected by construction activities carried out in its protection zone. The tree has an unnatural trunk slope. The trunk is overgrown by ivy (*Hedera hedelix* L.) A concrete wall with metal fencing encroaches on the protection zone of the tree; it grows into the tree trunk from the right side and tilts it all the way to the left side. The tree has a minimal room to grow as there is flagstone cladding and stone steps throughout the area approximately 50 cm from the trunk. The roots do not have enough space as they are weighed down by the concrete. In this case, the prohibition to 'carry out ground shaping' (s.49 (7) (e) and 'construct a property fence' (s.49 (7) (f)) in the protected tree zone is violated. Although it is a deep rooting tree, it would be necessary to take acoustic tomography measurements to confirm the stability and safety of the tree and to implement technical measures to minimize the risk to pedestrians and property if the tree were to be uprooted.

The pedunculate oak (*Quercus robur*) (reg. no. 221; fig. 1d) is located in a quiet area of the Old Town (side street), in a fenced garden of private property, without public access. Visually, the tree shows no signs of damage. The tall specimen is located between buildings in a small area bounded by a concrete wall and fence. Because of the immediate contact with the buildings, its branches are often splayed. Local residents are asking for the protection to be lifted so that they can create a parking area for cars. In this case, the prohibition to "carry out ground shaping" (§49(7)(e)) and to "construct a property fence" (§49(7)(f)) in the protection zone of a protected tree has been violated. From the point of view of saving the tree on this site, it is necessary to carry out educational activities for local residents in order to promote the social and cultural significance of protected trees, especially in an urbanized environment.

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Fig. 1: A) Magnolia X Soulangiana Located on Palisády Street; B) Pinus Nigra Situated on Francúzskych Partizánov Street; C) Quercus Virgiliana on Šulekova Street; D) Quercus Robur Located on Moyzesova Street.

Results of a sociological survey

The questionnaire survey was administered to 514 respondents, 306 men and 208 women. The respondents were persons over 18 years of age, with primary, secondary and university education, living, working or both living and working in Bratislava. The highest number of respondents had university education (287). This was followed by respondents with secondary education (221) and the smallest sample of respondents was made up of respondents with primary education (6). In terms of residence, most respondents live and work in Bratislava (339), followed by respondents who travel to Bratislava for work (98) and the last group of respondents consisted of respondents who live in Bratislava (77). In terms of age structure, the sample was dominated by respondents in the 35-44-year age category (142), followed by respondents in the 45-54-year age category (117), then respondents in the 25-34-year age category, respondents in the 55-64-year age category (76), followed by respondents in the 65-plus age category (56), and finally the youngest respondents in the 18-24-year age category (20). The results of the questionnaire survey revealed the respondents' attitudes towards green infrastructure issues, the importance, significance and need of protected trees and large crown solitaires as point elements of green infrastructure in the urban environment. Respondents answered five closed-ended questions.

Question 1 – In your opinion, small-scale elements of conservation and landscape importance, such as protected trees or large-crowned solitaires, should be in the urban environment: removed, revitalized, preserved, planted or I do not know how to comment on this question?

The highest percentage of respondents would like to have more protected trees in the city (53 %), 32.5 % would like to keep the current number of trees, and less than one percent of respondents sees a need to revitalize trees in Bratislava. 13 % of respondents could not comment on the question (fig. 2). Only two respondents would like to remove a protected tree from the urban environment. In terms of personal characteristics, of the 306 men surveyed, almost 53 % would like to increase the number of protected trees in the city, as would almost 54 % of the total number of women surveyed (208). Of these, more than 51 % would be in favour of increasing the number of protected trees. 34.5 % would maintain the status quo and 1.4 % would prefer revitalization of existing protected trees. Only two women, in the age group of 45 to 54 years, with a university degree who travel to the capital for work, would like to remove existing protected trees by felling.

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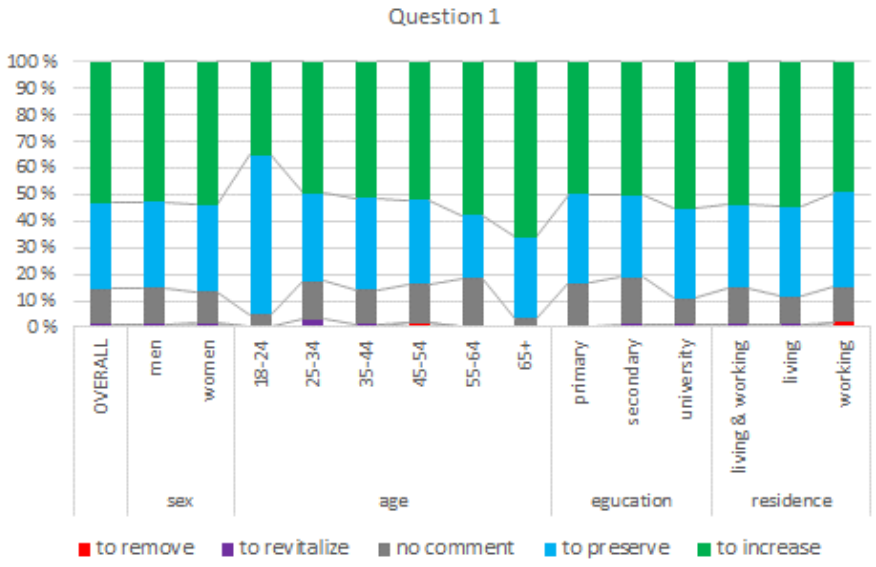

Fig. 2. Respondents' answer to Question 1.

Question 2 – Were the terms green infrastructure and blue infrastructure already familiar to you before filling in the questionnaire?

Almost 52 % of respondents answered that they were not familiar with the concept of green and blue infrastructure (fig. 3). 48% of respondents were familiar with the concept of green and blue infrastructure. A higher percentage of respondents who were familiar with the term rather than unfamiliar were in the 45-54-year-old category and over 65-year-old age groups with a secondary education who work in the city.

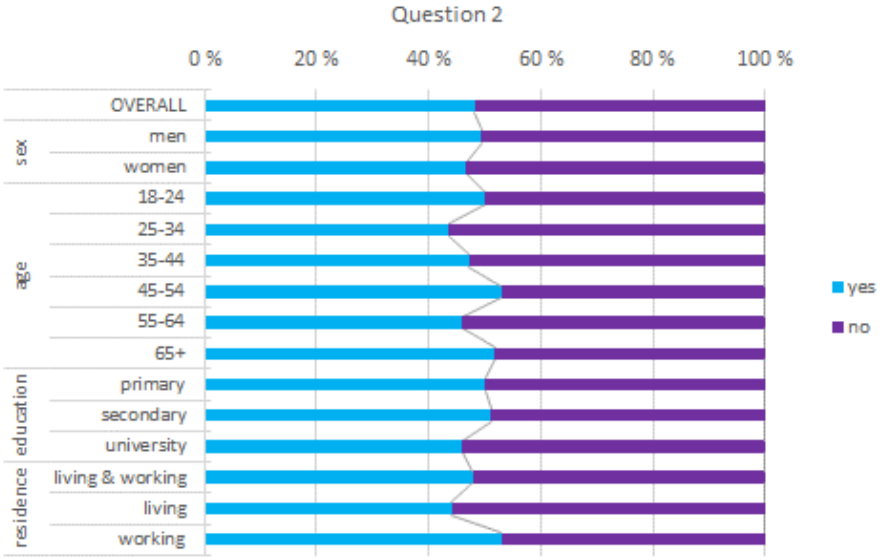

Fig. 3. Respondents' answer to Question 2.

Question 3 – Do you believe that increased care of green and blue infrastructure elements can contribute to solving environmental problems (such as prolonged droughts, extreme rainfall, heat, air/water/soil pollution, loss of biodiversity, etc.)?

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Of the total sample of 514 respondents, more than 91 % believe that increased care for green and blue infrastructure elements can contribute to solving environmental problems (fig. 4). The opposite opinion was held by 8.6 % of respondents. Women were more critical in their responses, with 10 % of them not thinking that increased care should contribute to solving environmental problems. Similarly, this opinion was shared by almost 12 % of respondents in the 45-54 age category, almost 10% of respondents with secondary education and more than 9 % of respondents working in Bratislava.

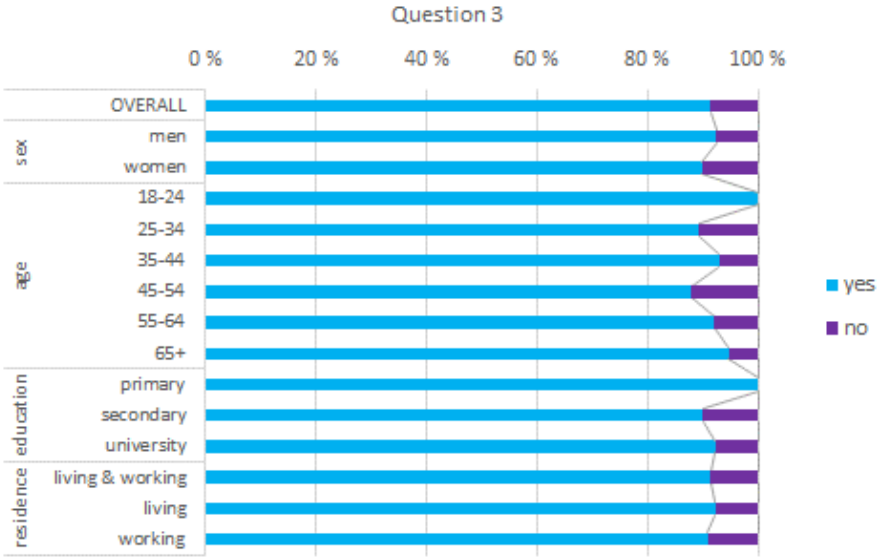

Fig. 4: Respondents' answer to Question 3

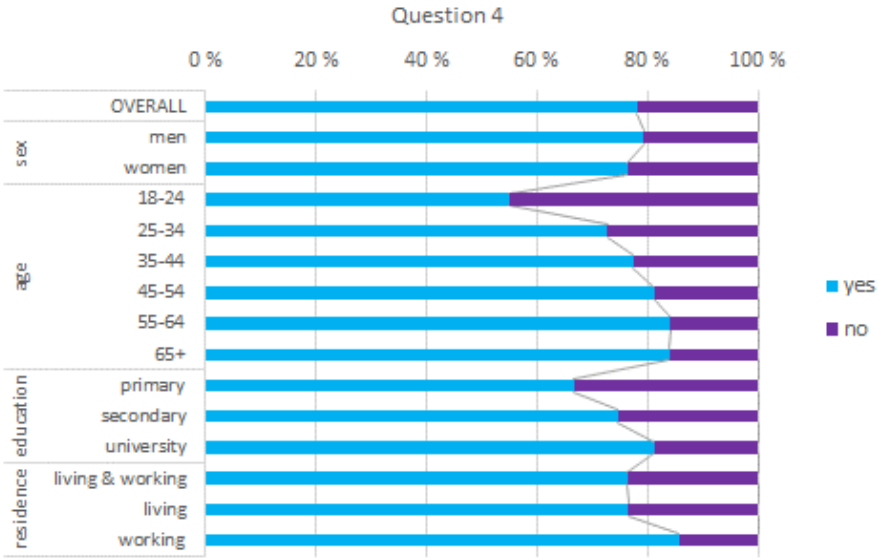

Fig. 5: Respondents' answer to Question 4

Question 4 – If you had the opportunity, would you be involved in the creation of green and blue infrastructure elements in your neighbourhood or in another part of Bratislava?

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Of the total number of respondents, 78 % of respondents would be involved in the creation of green and blue infrastructure features (fig. 5). In terms of percentage, men would be more active than women, the same as respondents of higher age categories, university educated, and working in Bratislava.

Question 5 – Do you agree with building functional elements of green and blue infrastructure in Bratislava at the expense of grey infrastructure?

More than 93 % of respondents think that Bratislava needs to build green and blue infrastructure elements more than grey infrastructure elements (fig. 6). Almost 7 % of respondents do not think that green and blue infrastructure elements should be built at the expense of grey infrastructure. This view was shared by 11 % of respondents in the 55-64 age category, 17 % of respondents in the primary education category and 8 % of respondents living and working in Bratislava.

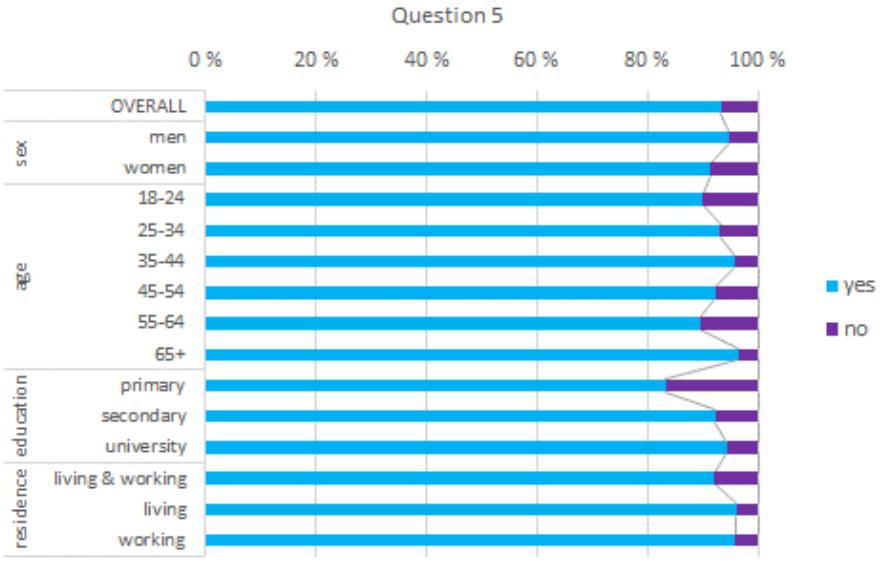

Fig. 6: Respondents' answer to Question 5

In terms of personal characteristics, the survey showed only slight differences in the responses across sex, age, education level and residence categories, which were not evaluated as statistically significant by the chi-square test. The research showed reserves in the conceptual literacy of the population, which can be addressed by more education and awareness-raising actions on green infrastructure issues. The following conclusions can be drawn from the responses:

the respondents perceive that addressing green infrastructure in the urban environment is relevant and necessary;

they also see the importance of green infrastructure in mitigating environmental problems;

they perceive the presence of protected trees as a point element of green infrastructure in the urban environment positively;

they want to maintain or increase the number of protected trees in the future;

where possible, they are keen to be involved in the construction of green infrastructure elements and thus contribute to reducing the disproportion between grey and green infrastructure in the urban environment.

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Discussion

According to Juhásová (1999), trees are damaged in 4 basic ways. Mechanically, by pests, diseases and other elements (physiological drought, lack of available nutrients, desiccation caused by unfavourable conditions, etc.). In practice, it is often a combination of several factors. The results of the field research were compared with information on protected trees listed in the List of Specially Protected Areas of the Slovak Republic. The State Nature Conservancy lists individuals that meet the object of protection, despite that several prohibitions are violated in their protection zone and the trees are threatened by several negative factors. Within the assessment of 15 prohibitions of activities in the protected zone of the trees, the prohibition to drive or stand with a motor vehicle was violated in two cases. In two cases, the provision forbidding the establishment of access roads for motor vehicles or sled vehicles was violated. In four cases, the prohibition to build a fence on the property was violated. In one case, the prohibition to deposit waste or store building material, timber or other material that may cause soil compaction over the root system of a protected tree was violated; and in one case, the prohibition to set or maintain an open fire, smoke or throw burning or smouldering objects or handle combustible materials or burn vegetation cover was violated. In this case, a no smoking sign would need to be placed near the protected tree, because it is located in the hospital garden, in the immediate vicinity of the benches, where patients and visitors often smoke (fig. 7a).

Protected trees in Bratislava are also threatened by other negative factors. Two individuals are exposed to negative impacts from ongoing construction activity (increased dust), six individuals are under the negative impact of automobile traffic (exhaust fumes), seven individuals have been exposed to construction activity in the past (construction of buildings, sidewalks, fences and walls, etc.), two protected trees are in contact with power line wires, the roots of four trees are under asphalt pavement and two individuals are overgrown by ivy (reduces light). Other factors, such as accessibility to the trees, also influenced their assessment. Of the total number, ten trees grow in private fenced yards and gardens without public access. Of this number, in three cases we have repeatedly failed to contact landowners who would allow us access to their land. In four cases we did not find protected trees in private gardens as listed by the State Nature Conservancy, so we assume they were illegally cut down. The other trees in private gardens are watered and tended by the residents of the houses, unfortunately without financial support from the State Nature Conservancy. Ten protected trees growing in public areas of parks, gardens of schools, museums and hospitals also have regular care - pruning of dry branches, crown fixation, use of irrigation bags in dry season, etc. (fig. 7b).

From the point of view of horticultural value (Machovec, 1982), all evaluated trees can be classified as very valuable and they should be preserved as much as possible on a given site, even at the cost of reconsidering and redesigning the horticultural space, planned development, etc. Their removal is possible only in exceptional cases (Machovec, 1982). For *Quercus virgiliana* (214) with moderately reduced static vitality, we propose to verify the stability of the tree by a tomogram. For *Cercis siliquastrum* (235), due to the pronounced cavity in the tree, we can classify it as a below-average tree (Machovec, 1982) (fig. 7c).

Fig. 7: a) Catalpa bignonioides located on Mickiewiczova Street; b) Sophora japonica situated on Vajanského nábrežie Street; c) Cercis siliquastrum on Galandova Street.

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Improvement in the quality of these trees cannot be assumed, however, as they are unique and protected individuals they should be retained for survival (Machovec, 1982). In the case of *Cercis siliquastrum* (235), it would be necessary to verify the stability of the tree by a tensile test or acoustic tomograph measurements. The List of Specially Protected Areas of the Slovak Republic also lists individuals with a valid protection document, despite the fact that they no longer physically exist, such as *Pinus strobus*, *Betula papyrifera*, *Castanea sativa*, *Abies concolor* (217, 223, 228, 225). These are specimens of trees that were in the gardens of private properties and were removed by unauthorised felling. In this case, a complaint should be lodged with the Environmental Inspectorate to investigate the matter. Also listed is an 80-year-old "Devínská oskoruša sorb tree" *(Sorbus domestica*) (495) in a local area called Zelené terasy, where the reason for protection is no longer valid, as the tree has dried up after being struck by lightning. Based on the results of the research, it would therefore be necessary to update the information in the national register of protected trees. In particular, data on the number of individuals, height and circumference of the trunk, protection status, whether the reason for protection has expired, as well as the degree of threat, the date of validity of the document, etc., as these data in several cases do not correspond to the real situation. The research also shows the need to regularly check compliance with the legislative provisions on tree protection. In case of violation, corrective measures should be implemented in order to preserve the conditions for the existence of protected trees as far as possible. This also applies to the siting of new buildings, the construction of fences and the establishment of access roads for motor vehicles, where it is necessary to consider the annual increase in the perimeter of the trunk. Residents who have a protected tree in their own garden should be provided with financial resources for their care and maintenance. For trees with compromised stability, a tomography should be taken to eliminate the potential risk to the health and property of residents. More education is also needed to raise awareness of the importance of protected trees and the need for their care and protection. Last but not least, there is a need to increase the number of qualified staff in the State Nature Conservancy service, especially dendrologists, so that field work can be carried out more frequently than once every 2-3 years, which is insufficient.

Conclusion

The development of urban or rural areas of Slovakia depends on taking care of the quality of landscape components and elements, including protected trees. The reason for protecting trees in Bratislava is their high biological and aesthetic value and their rare occurrence. They are mostly single specimens important from a cultural, historical, scientific, landscape and aesthetic points of view. All the protected trees surveyed in the area of the capital city of Bratislava are under the management of the Dunajské luhy Protected Landscape Area and are under the 2nd level of protection of the national scale. If we want to preserve the trees as a cultural heritage that has existed here for hundreds of years, we must strictly observe the legally established protection zone according to §49, paragraph 5 (in the case of a declared protection zone - the area within a radius of 15 m from the trunk of the protected tree) and fully respect the prohibition of activities defined in §49, paragraph 7, points a) to o).

Our research has shown that it is important not only to declare a tree as a protected one but above all to ensure its care and protection. The results of the landscape-ecological research and sociological survey will be used in the creation of a database of green infrastructure elements as well as in the assignment of degrees of landscape-ecological significance to green infrastructure elements within the VEGA project. Information on the occurrence, number, health status, potential sources of threat and opinions of respondents from the sociological survey can be included in management measures in urban development plans. Their acceptance in development documents will contribute to the improvement of the quality of the settlement environment and to the conservation of the species diversity of the natural gene pool at the local level.

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