

Evaluation of urban green spaces in Bratislava

Tamara Reháčková¹⁾ and Eva Pauditšová²⁾

¹⁾ *University of Comenius in Bratislava, Faculty of Natural Sciences, Section of Environmental Science, Department of Ecosozology and Physiotactics, Mlynská dolina B2, SK-842 15 Bratislava, Slovak Republic (e-mail: rehackova@fns.uniba.sk)*

²⁾ *University of Comenius in Bratislava, Faculty of Natural Sciences, Section of Environmental Science, Department of Landscape Ecology, Mlynská dolina B2, SK-842 15 Bratislava, Slovak Republic*

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Current land-use patterns in Slovak towns are undergoing a rapid change. The ratio of built-up spaces to green spaces is increasing. Green areas in the urban environment need to be preserved for their recreational, hygienic and aesthetic functions. A further reason is that green areas serve also ecological functions. This contribution deals with the topic of evaluating the urban green spaces in Bratislava. The green spaces were mapped at two levels. The first level included the areas larger than 10 ha: forests and forest parks; complexes of private gardens, allotments and weekend cottage gardens. The second level contained green spaces with the area between 0.5 and 10 ha: remnants of natural vegetation; parks; landscaped surrounds around housing estates and commercial premises; tree-lined avenues, alleys, roadside verges; cemeteries and historical cemeteries. The results of this research besides the geographic distribution of green spaces, their areas, origin, composition of plant species and woody growth structure also include data on the functionality of individual categories of green areas.

Introduction

Green spaces are considered to have a sovereign meaning in the improvement of the environment quality within urban areas. The green areas (patches) in the urban environment are represented by various types, such as: (1) remnants of original ecosystems, so-called remnant patches (Forman and Godron 1986) such as: forests, forest parts, vegetation along rivers, etc.; (2) the various types of man-created, or managed areas such as: parks, gardens, tree-lined avenues, cemeteries, landscaped surrounds around housing estates and commercial premises, etc.; and (3) areas where natural succession occurs due to the absence of direct human influence. Forman and

Godron (1986) defined such areas as regenerating patches that are represented by various sites with ruderal vegetation (abandoned courtyards, abandoned gardens, areas of destroyed buildings, unused plots, etc.).

The matter of urban green spaces is very wide and complicated. Several authors studied the position and importance of green areas and their functions in cities (e.g., Jurko 1990, Bradshaw *et al.* 1995, Nilsson and Randrup 1997, Supuka 1998, Alm 1999, Randrup *et al.* 1999, Škiljajica *et al.* 1999, Attwell 2000, Gobster 2001, Vratuša and Anastasijević 2001, Reháčková 2002, Supuka 2002, Reháčková and Pauditšová 2003). A wide spectrum of functions in view of green spaces in cities was defined



Fig. 1. Location of the study area within the Slovak Republic.

by Sukopp and Weiler (1988). These functions are particularly: protection of species (refuges, centres for reproduction of species, corridors), identification with neighbouring areas, recreation, environmental changes and air pollution indicators, ecological research, water quality, climate and air quality, noise cover.

It is possible to evaluate the functions and significance of green areas in cities on a high-quality level only when comprehensive data on individual green areas including parameters like the area, origin, species composition, structure, etc. are available.

In the territory of Bratislava, the capital of the Slovak Republic, significant green areas have so far not been mapped or evaluated in a comprehensive way. Studies of the quantitative and qualitative evaluation of vegetation carried out in the past were aimed at selected parts of Bratislava only. Their results were not intercomparable since the investigated categories of greenery and their characteristics were not homogenous. We started from this fact in setting the objectives of our research.

Bratislava is a typical urban area made of varied land-use forms and different urban structures which determine the occurrence of green spaces. The following objectives were set in the research: (1) to map all green surfaces with the area over 0.5 ha according to unified criteria within all 20 cadastres (cadastre = basic territorial unit) in Bratislava, and (2) to evaluate the functionality of individual categories of green areas.

Study area

Bratislava is the capital city of the Slovak Republic (Fig. 1). Its area is 36 759 ha and the number of inhabitants is 428 672. The town is situated

on both sides of the Danube river. The relief of the town is quite dissected. The northern part extends to slopes of the Malé Karpaty Mountains (altitude 162–559 m). The southern sector is of a lowland character; it is a part of the geographical unit of the Podunajská nížina lowland with altitude reaching 200 m above sea level.

The city in its present form is a result of linking its historical centre with the surrounding villages. The study area consists of 17 municipalities represented by 20 cadastres.

Methods

Mapping the green areas

All types of green areas were mapped on the scale of 1:1000 at two levels. The first level included the areas larger than 10 ha: forests and forest parks; complexes of private gardens, allotments and weekend cottage gardens. The second level of mapping contained the green spaces with the area between 0.5 and 10 ha: remnants of natural vegetation; parks; landscaped surrounds around housing estates and commercial premises; tree-lined avenues, alleys, roadside verges; cemeteries and historical cemeteries. We recorded the following parameters: the area, origin, plant species composition and woody growth structure for each category.

The mapping of green areas at both levels was carried out in 2002–2003. The results from field research were entered into the geographic information system in a graphic (vector) as well as an attribute form. The graphic component was represented by the area and linear elements. The database comprised: (1) numerical data: the green space category code, its area (in the case of a tree-lined avenue/alley it was its length), its perimeter, the plot number, the value of functionality; (2) verbal data: the name of a cadastral territory, that of an administrative unit, the localisation of a green area by street.

First mapping level

The first mapping level consisted of two categories. (1) Forests and forest parks included the

woodland resources in the particular cadastres in the study area. We recorded the natural, semi-natural and also non-indigenous forests. Since the zoological garden is a part of a forest park it was also included in this category. (2) Green areas formed by private gardens, allotments and weekend cottage gardens. The functionality of individual gardens is not very high therefore we mapped the complexes of gardens, where the single-family house properties had an average of 70% of the area covered by vegetation.

Second mapping level

The second mapping level consisted of five categories: (1) Parks — the historical parks in different garden styles with a high cultural value and the parks that were created during the building of new housing estates in the city in the 1960s, 1970s and 1980s. Typical entities of these green areas are the playgrounds, fountains, benches, sculptures, lights, paths, etc. (2) Remnants of natural vegetation — fragments of forests and vegetation bordering rivers, streams and roads. (3) Landscaped surrounds around housing estates and commercial premises (e.g. hospitals, schools). (4) Tree-lined avenues, alleys and roadside verges — in the case of alleys we measured their length. (5) Cemeteries and historical cemeteries.

Evaluating the functionality of individual categories of green areas

The presupposition of direct dependence between the functionality of green areas, their species composition and growth structure (horizontal and vertical structure, age) forms a basis of the applied methodological procedure. The resistance of particular woody species against pollution is considered a very important assessment criterion. Mostly, resistance against SO_2 , H_2S , NO_x , CO , O_3 , C_x , compounds of F, Cl, Pb, and salt effect was considered.

In order to find out the overall functionality of a respective category of green areas it was necessary to determine functionality for each mapped area of verdure separately. In evaluating, we

started from the fact that green areas may simultaneously fulfil several functions that we divided into two groups: anthropocentric and biocentric. The group of anthropocentric functions included the hygienic function being understood in the sense of its positive impact on microclimate, the isolation function with importance for noise abatement and dust particles elimination, as well as the recreational function. The group of biocentric functions was represented by the ecological function (formation of the environment), the topic function (refuge provision) and the trophic function (food resources provision).

All the above-mentioned functions were evaluated in each green area with the help of the following three-degree scale:

1. Low functionality value (value 1): a woody growth is one-layered only; it has the same age; trees are positioned individually or in small groups; the composition of species is unsuitable with a high representation of species sensitive to air pollution and salt effect; the share of species significant from the trophic aspect is low.
2. Mean functionality value (value 2): a woody growth is slightly connected; the presence of individual layers is not balanced; the age heterogeneousness is weak; the composition of species is partially resistant against effects of human activities (air pollution, salt effect); the composition of species in view of their trophic function is partially suitable.
3. High functionality value (value 3): a woody growth is with acceptable interconnection and the presence of individual layers; the composition of species resistant against negative effects of human activities is appropriate; the composition of species as to their trophic function is suitable.

Functionality of single-evaluated categories of green areas was calculated with the formula:

$$F_x = \frac{\sum_{i=1}^n f_i}{n} \quad (1)$$

where F_x = the overall functionality of green areas within one category, f_i = the functionality of individual green areas (within one evaluated

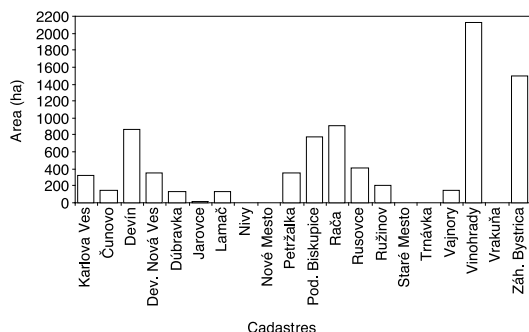


Fig. 2. The area of forests and forest parks in Bratislava.

category), and n = the number of evaluated green areas within one category.

The obtained values of functionality of green areas related to the evaluated categories were within the following intervals:

- low functionality value = 1.0–1.6,
- mean functionality value = 1.7–2.3,
- high functionality value = 2.4–3.0.

Results

Green areas

First mapping level

Forests and forest parks (category 1) are situated in the north-western, northern and southern parts of the city. The hillsides of the Malé Karpaty Mts. are covered by Carpathian oak–hornbeam forests. Floodplain forests may be found in the southern part of Bratislava. The whole area of both categories was 8345.31 ha. The area of forests in the individual cadastrals is depicted in Fig. 2.

The origin of these forests is mostly natural or semi-natural but artificially planted forests made of alien species occur too. Forests and forest parks in the northern and northwestern parts of Bratislava belong to the alliance *Carpinion betuli* Issler 1931. The dominant tree and shrub species here were (Červenka *et al.* 1986): *Carpinus betulus*, *Quercus petraea* agg., *Cerasus avium*, *Acer campestre*, *Acer platanoides*, *Fraxinus excelsior*, *Pyrus pyraeaster*, *Fagus sylvatica*, *Tilia cordata*, *Sorbus torminalis*, *Lonicera xylosteum*, *Swida sanguinea*, *Corylus avellana*, *Ligustrum vulgare*, *Crataegus monogyna*, *Euonymus europaea*, also mixed with *Euonymus verrucosa*, *Staphylea pinnata* and *Rhamnus cathartica*. Forests and forest parks in the south of Bratislava belong to the alliance *Salicion Albae* Oberd. 1953. The most significant species here are: *Salix alba*, *Salix fragilis*, *Populus nigra*, *Populus alba*, *Populus x canescens*, *Swida sanguinea*, *Sambucus nigra*, on the higher terrain levels *Fraxinus excelsior*, *Fraxinus angustifolia*, *Ulmus laevis* also occurred. The combination of species in the Bratislava forest region was nearly close to the combination of species within natural Carpathian oak–hornbeam forests and floodplain forests. Also the growth structure is favourable; all three levels (trees, shrubs and herbs) are here well developed.

Private gardens, allotments and weekend cottage gardens (category 2) are localised in all city cadastrals, mainly in the suburban area. The large agglomerations of allotments and weekend cottage gardens are situated on the hilly parts of the town, originally covered by forests. The entire area of this green category was 1735.40 ha. According to their origin and a high proportion of alien species present, we classified these areas as artificially created by man. The combination of species here was very diverse; favourable were coniferous species (*Pinus nigra*, *Pinus silvestris*, *Picea alba*, *Picea pungens*, *Chamaecyparis lawsoniana*, *Thuja occidentalis*, etc.). Often fruit trees and grapevines could be found there. The growth structure was quite heterogeneous. All three levels (trees, shrubs and lawn) occurred in the majority of cases.

Second mapping level

Second mapping level

In total 395 areas in five categories (Table 1) were mapped at the second level. The proportion of evaluated categories in the individual cadastrals is illustrated in Fig. 3.

The parks (category 1) in the city territory occur unevenly. Out of 20 evaluated cadastrals, they were recorded only in seven cases. The area of parks in Bratislava represented only 1.71% (123.4 ha) out of the whole urban area. The origin of park areas is mostly artificial; however

in certain cases the remnants of original growths were preserved. In the parks we found many interesting evergreen, deciduous or coniferous woods (*Pinus ponderosa*, *Ginkgo biloba*, *Pseudolarix amabilis*, *Metasequoia glyptostroboides*, *Pseudotsuga canadensis*, etc.) and also their coloured or shaped cultivars (*Fagus silvatica* “*Atropurpurea*”, *Morus alba* “*Pendula*”, *Quercus robur* “*Fastigiata*”). Out of the common species particularly *Acer pseudoplatanus*, *Acer platanoides*, *Betula pendula*, *Tilia cordata* and *Pinus nigra*. The growth structure reflects a corresponding garden style.

The remnants of natural vegetation (category 2) occurred especially in suburban areas. However, in many cases we detected them in central parts of the city. The whole area of these remnants of natural vegetation accounted for 372.05 ha. The origin of these remnants is derived from pristine growths that were preserved in the territory in larger or lesser areas. Forest fragments with the combination of species similar to Carpathian oak–hornbeam forests or floodplain forests were the most dominating. The linear features occurred along some streams (*Alnus glutinosa*, *Salix alba*, *Salix fragilis*) or along country roads (*Populus nigra*, *Robinia pseudoacacia*). Their structure was often disturbed by various anthropogenic influences.

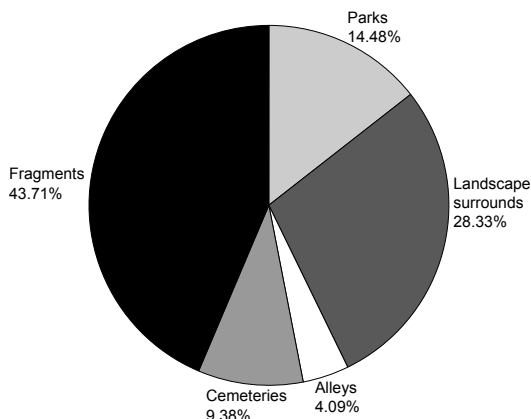


Fig. 3. The proportion of evaluated categories mapped at the second level.

The landscaped surrounds around housing estates and commercial premises (category 3) are the typical green areas in the newest parts of the town. These plantings date back to the 1960s,

Table 1. Number of mapped green spaces with the area of 0.5–10 ha.

Cadastrs	Parks, historical parks	Landscaped surrounds	Alleys, roadside verges	Cemeteries	Fragments of natural vegetation
Čunovo	0	1	1	1	0
Devín	0	1	2	1	3
Devínska Nová Ves	0	10	6	1	2
Dúbravka	2	7	1	1	2
Jarovce	1	0	2	1	1
Karlova Ves	4	18	1	2	8
Lamač	0	5	2	1	0
Nivy	4	8	34	0	0
Nové Mesto	4	11	15	0	0
Petržalka	3	17	1	1	7
Podunajské Biskupice	0	7	4	2	0
Rača	1	7	12	1	2
Rusovce	2	3	0	1	0
Ružinov	2	15	0	2	3
Staré Mesto	9	13	72	6	4
Trnávka	0	3	0	0	0
Vajnory	1	1	8	1	2
Vinohrady	0	1	0	0	3
Vrakuňa	1	3	2	2	2
Záhorská Bystrica	0	1	1	2	0
Total	34	132	164	26	39

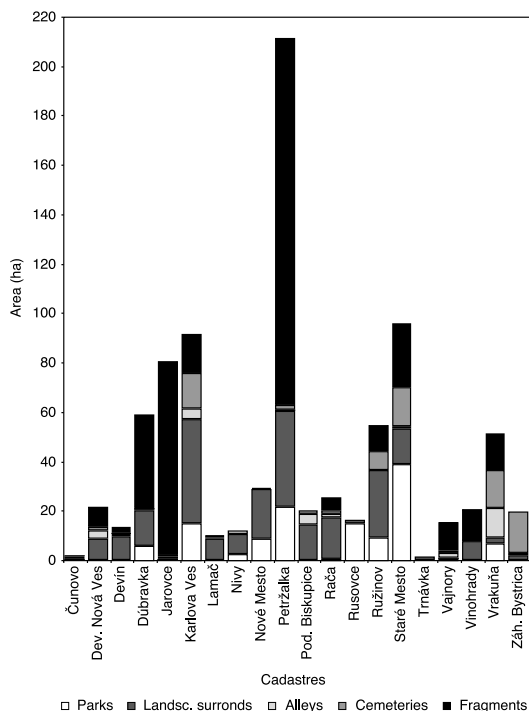


Fig. 4. The area of green spaces in Bratislava's cadastral areas mapped at the second level.

1970s and 1980s — i.e. the age of plantings is 20–40 years. These types of green areas consist of open spaces or they are situated in enclosed yards. The whole area of the given green category was 241.13 ha. The origin of growths was exclusively artificial; these areas have been created and managed by man. In the combination of species common ones were: *Acer platanoides*, *Acer pseudoplatanus*, *Betula pendula*, *Negundo aceroides*, *Tilia cordata*, *Pinus nigra*. Generally, the structure of these plantings is not suitable; characteristic is the lack of shrubs, while grasses in these areas predominate.

The tree-lined avenues and alleys (category 4) are concentrated in four cadastral areas. They occur rarely in the remaining areas. The number of tree lines was 122 and their length about 40 km. In all cases they were created by man. The following taxa were found in the species combination: *Celtis occidentalis*, *Sophora japonica*, *Fraxinus americana*, *Tilia cordata*, *Acer platanoides* etc. The roadside verges (34.85 ha) consisted of — besides species mentioned above — *Swida alba*, *Elaeagnus angustifolia*, *Rosa rugosa*, etc.

We recorded the cemeteries (category 5) in 16 cadastral areas. The total number of cemeteries is 23, their area was 79.87 ha. Cemeteries are mostly concentrated in the oldest part of the town (the cadastral area of Staré Mesto). They have been created exclusively by man. Typical species here were: *Aesculus hippocastanum*, *Tilia cordata*, *Tilia platyphyllos*, *Thuja occidentalis*, *Thuja orientalis*. In the growth structure tree species predominated, shrubs and lawns were almost absent. The area of green spaces mapped at the second level is illustrated in Fig. 4.

An example of mapping the green areas is shown in Fig. 5. This exemplifies both mapping levels in a selected area — the cadastral area of Devín.

The functionality of green areas

The functionality of each mapped green area was evaluated separately in accordance with the methodological procedure. Tables 2 and 3 present the overall functionality of individual functions within the evaluated categories of green areas.

The evaluated green areas represent a wide range of functions. The category “forests and forest parks” achieves the highest values of functionality, namely for all functions. It is a consequence of the favourable structure of growths and their species composition. This makes ideal presuppositions for the existence of wildlife and provides possibilities for recreational utilisation too. According to our findings, the category “the remnants of natural vegetation” has also a high value of functionality. On the other side, the category “tree-lined avenues, alleys and roadside verges” is marked with the lower values of functionality. Such a negative state is caused by the unsuitable structure of growths and their inappropriate species composition (e.g. the frequent occurrence of species sensitive to salt effect). The other categories of green areas were evaluated as areas with the mean value of functionality.

Discussion

As to the area, the most significant green spaces in Bratislava are forests, forest parks, private

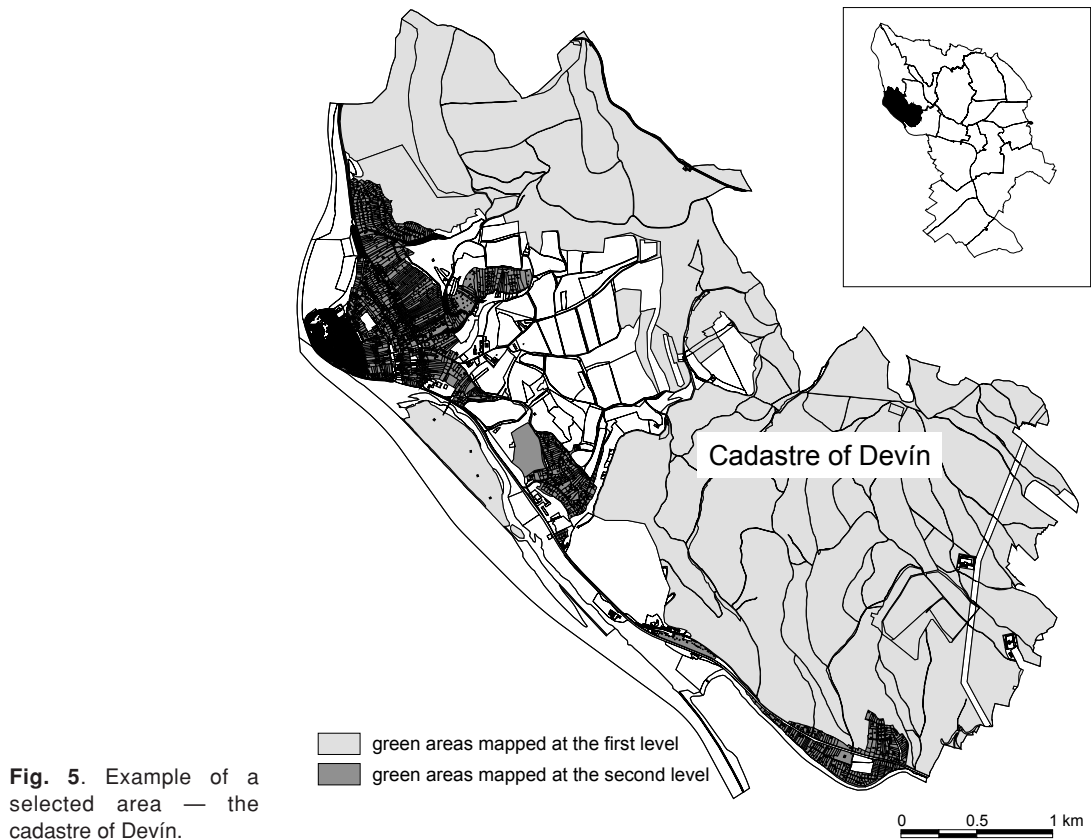


Fig. 5. Example of a selected area — the cadastre of Devín.

Table 2. Value of functionality in green areas mapped at the first level.

Category of green areas	Hygienic function	Isolation function	Recreational function	Ecological function	Trophic function	Topic function
Forests and forest parks	3.0	2.9	3.0	3.0	3.0	3.0
Private gardens, allotments and weekend cottage gardens	2.3	1.8	3.0	2.4	2.9	2.9

Table 3. Value of functionality in green areas mapped at the second level.

Category of green areas	Hygienic function	Isolation function	Recreational function	Ecological function	Trophic function	Topic function
Parks, historical parks	2.2	2.1	2.8	2.2	2.3	2.2
Remnants of natural vegetation	2.5	2.3	1.7	2.8	3.0	2.8
Landscaped surrounds around housing estates and commercial premises	2.1	2.3	2.5	1.9	2.3	2.1
Tree-lined avenues, alleys and roadside verges	1.4	1.6	1.2	1.6	1.7	1.2
Cemeteries and historical cemeteries	1.7	1.6	1.4	2.3	2.8	2.8

gardens, allotments and weekend cottage gardens. Their share in all mapped green spaces at both levels was 91.67% (i.e. 10 080.71 ha). These spaces with the area over 10 ha made up 27% out of the entire examined territory. Forests mostly occur in the cadastral territories extending on slopes of the Malé Karpaty Mts. Private gardens, allotments and weekend cottage gardens occur in all cadastral territories. This category of green spaces had the smallest area in cadastral territories where blocks of flats and industrial objects dominate. The overall area of green spaces mapped at the second level was 915.44 ha. The most common within these areas are remnants of natural vegetation. This category predominated in the cadastral territories of Petržalka and Jarovce. The category of landscaped surrounds around housing estates and commercial premises is the next most frequent. These green areas are related to territories with the prevailing mass house building from the 1960s, 1970s and 1980s.

The share of all green surfaces mapped at both levels accounted for 29.91% (i.e. 10 996.15 ha) out of the entire area of Bratislava. Stanners and Bourdean (1998) give that Bratislava along with the cities of Gdańsk, Kyjiv and Zagreb belong to the settlements where the green areas make up over 30% of the city area. This datum is slightly different from our findings, which may be caused by the fact that we included only the areas over 0.5 ha in our evaluation. Regarding the area of green spaces per one inhabitant, it is 21.35 m² per person when we take into consideration the areas mapped nearly at the second level. This figure fully corresponds to data given in a work by Stanners and Bourdean (1998). The cities of Ljubljana and Sofija are at the same level. When the areas mapped at the first level are also included in the evaluation, we obtain the figure of 256.51 m² per person. We consider this value to be very favourable.

The special study of land use in the territory of Bratislava including the evaluation of green areas was also conducted by Divinský (2000) who applied a similar categorisation of green surfaces as the authors of this contribution. His evaluation was carried out within the so-called morphological city that represents only a part of the city in its administrative limits therefore findings of this work are not fully comparable with ours.

The plant species composition in areas created and managed by man is relatively varied. The 72 genera of deciduous and coniferous woody plants were recorded as usually occurring. Sukopp and Henke (1989) give a comparison of flora in nine European cities. This showed that 25% to 30% of species belong to the common urban flora. The following species occurred in over 50% of all localities in the studied territory: *Acer platanoides*, *Acer pseudoplatanus*, *Betula pendula*, *Tilia cordata* and *Pinus nigra*. For comparison, Kunick (1983) gives the following eight species from the suburban parks in Köln: *Acer pseudoplatanus*, *Betula pendula*, *Robinia pseudoacacia*, *Fagus sylvatica*, *Carpinus betulus*, *Pinus nigra*, *Taxus baccata* and *Aesculus hippocastanum*. They occurred in more than 50% of all examined growths. Riedl (1989) gives 52 species of planted trees from the suburban parks and cemeteries in Essen. Out of them 5 species occurred in over 30% of the studied area: *Acer pseudoplatanus*, *Acer saccharinum*, *Betula pendula*, *Carpinus betulus* and *Quercus robur*. According to Wittig (1998), the most spread tree species in Central European towns is *Betula pendula*. Natural species *Acer pseudoplatanus*, *Acer platanoides*, *Acer campestre*, *Carpinus betulus*, *Tilia cordata*, *Quercus robur*, *Sorbus aucuparia*, *Fraxinus excelsior* within alien species coming from southern Europe — *Aesculus hippocastanum* and *Pinus nigra* — are very frequent. Then fruit trees — mainly apple trees, pear trees and cherry trees — are relatively frequent in gardens of old villa quarters. Currently, coniferous trees and their cultivars are preferred in privately owned plots. According to our findings, the species composition of woody plants in the studied territory of Bratislava is very similar to those given by the aforementioned authors.

In total, six selected functions significant from the anthropocentric aspect (hygienic, isolation and recreational functions) as well as from the biocentric one (ecological, trophic and topic functions) were evaluated. Traditionally, settlements are perceived as an environment unsuitable for wildlife. Our research proved right that those functions of green areas as the formation of living space, food resources provision and refuge provision noticeably increase their overall functionality.

The functionality of green areas from the point of view of noise abatement, dust elimination, positive impact on microclimate and the like achieves lower values compared to the biocentric functions. However, evaluated green areas have large reserves in the structure of growths influencing the above-mentioned anthropocentric functions.

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