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ANALYSIS OF PARK ZAIMOV WOODY VEGETATION IN SOFIA, BULGARIA

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Abstract

The aim of the research was assessment of the vegetation in park Zaimov, situated in the central part of Sofia. The used methods represent a new approach for more profound assessment of urban green spaces vegetation in Bulgaria, in more than one aspect. Therefore, those methods could be a subject of improvement and development in future studies. All woody vegetation of the park was taxonomically identified and mapped. Forty-four tree species from 27 genera were registered in the park. The individuals count 1156 trees with calculated relative effective volume (REV) of 79,511.45 m^3. This volume decreases 10 times during winter, which makes the park vegetation inefficient during this period. The vegetation is in good condition except trees at the south border of the park. Models of the tree crowns of four common species, well presented in the park, were made. The aesthetic values of the presented species give well-balanced and enough in quantity ornamental accents to the park environment in the different times of the year. The valuable old vegetation should be preserved in future reconstructions and better care should be provided to the new planted one. A strong suggestion for building a denser hedge barrier of evergreen vegetation across the south border or the park was made.

Key words: alley trees, species diversity, tree crown parameters, urban green spaces, vegetation condition.

Introduction

Providing healthy and aesthetic environment in big cities is one of the biggest challenges of the modern society. Urban nature fulfils important immaterial and non-consumptive human needs (Chiesura 2004). Failure to provide the restorative and psychological benefits of access to nature in the city could have substantial health costs in the long run (Thompson 2002). Sofia is the biggest city and capital of Bulgaria, hosting more than one fourth of the country's population. It has dramatic issues with air quality, especially during winter. There are several main factors which contributed to the air pollution, and the measures are mostly late and insufficient. According to the European Environment Agency (EEA) report Bulgaria is amongst the countries with worst air quality. It is also on top of the list for most years of life lost (YLL) attributable to particulate matter 2.5 μm of less (PM2.5) (EEA 2018).

Sofia is still one of the European capitals with most square metres of urban greenery, as a result of the partly preserved Adolf Muesmann's master plan for the green system (Kovachev et al. 2012). The attention in analysing and regulating the urban greenery was focused on quantity parameters of the green system than quality ones (Kovachev 2005). Furthermore, Sofia is losing more and more green areas due to urbanization and the quality of the existing ones has been dropping due to bad maintenance. Most of the public park reconstructions are implemented unprofessionally and without the needed preceding analysis. As a result, valuable vegetation is removed from places where it is absolutely essential, trees are planted where they can't develop and fulfil their ecological function, or the lack of maintenance limited their chance to survive.

Park Zaimov is one of the most visited parks in Sofia's central part. It covers around 10 hectares and was constructed between 1950 and 1960 on the place of old military barracks, situated in the margins of the city by that time. As Diko Dikov commented: There was built the residential complex Zaimov, now Oborishte, and the park in front of it. From the beautiful gardens in front of the barracks, only few huge poplars were kept (Dikov 2010) (Fig. 1).

The plan composition of the park is geometric with parterres, water effects and sculptures along the main axis. The park hosts various cultural, entertainment and sport events and was the first public space in Sofia with free Wi-Fi. In spite of the undoubtedly high value of the park, there isn't full description of the park vegetation, its ecological and aesthetic value, (health) status, functional capacity and biodiversity. Furthermore, Sofia Municipality aims to reconstruct and renovate the park in 2020 (Official statement of Sofia municipality – Anonymous 2019a).

The aim of the study is to make objective assessment of the woody vegetation of the park and to give recommendations for future reconstructions, so to maximize the benefits of this urban green area.

Fig. 1. Park Zaimov when built (Anonymous 2019b).

Materials and Methods

All woody plants in the park were taxonomically identified. They have been categorized as broadleaves or conifers and mapped. The diameters at breast height (DBH) of the old individual trees were measured. Diameter of new planted trees and trees with trunk diameter distinctly less than 10 cm was not measured. They were considered less than 7.62 cm for calculations after the Nowak et al. (2007) formula. The height of the trees and the crown height were measured with altimeter Blume-Leiss Model BL6. The crown diameter was measured as projection of the crown on the ground. The density of the crown was estimated by sight for every individual tree and they were divided into 3 groups: with dense (70–100 %), medium (40–70 %) or sparse (10–40 %) crown. A complete map of the vegetation was made, showing the foliage volumes in the park during active growing season (July) and during winter (January). For the purpose of the study, vegetative objects (trees and shrubs) were categorized in different height categories – 0–2 m, 2–5 m, 5–10 m, 10–15 m, 15–20 m, over 20 m. The relative effective volume (REV) of the vegetation in the park was calculated as function of the absolute volume of the crown (AVC) (calculated mathematically), the density of the crown defined in percentage, and coefficient take into consideration the months with leaves (1 for evergreen vegetation and 0.5 for broadleaves). Although very relative, calculating the effective volume will give possibility to compare different urban green spaces by REV per m^2, which can give us a clue about the ecological benefits and air quality relations, as well. Using the collected data about individual tree crowns, model of the crowns of four common species of alley trees in the park, at age of around 60 years, were made. Trees and shrubs aesthetic value was estimated and they were categorized as ‘species with ornamental flowers or fruits’ (ff), ‘species with autumn leaf colour effect’ (ace), ‘species/cultivars with permanent leaf colour effect’ (pce), ‘evergreen species’(e), ‘species with ornamental bark’(ob), ‘cultivars with ornamental crown form’(ocf). The health status of the trees was estimated according to the 5-grade scale with: 0 – fully healthy tree, 1 –satisfactory health status, 2 – unsatisfactory, 3 – poor, 4 – dying or fully dead tree (Pencheva 2017).

The tree crown parameters ware analysed by Analysis of Variance (ANOVA) and Post Hoc LSD test using SPSS 19.0 (SPSS for Windows 7).

Results and Discussion

Diversity and aesthetic value of the species in the park

All 1156 individual trees in the park were representatives of 44 species (27 genera). From them 13 species with 283 individuals were conifers and 31 species with 873 individuals – broadleaves (Table 1, Fig. 2A). From all trees 155 are young, planted less than 5 years ago. The new planted species are mostly ornamental trees with big aesthetic value like *Acer platanoides* L. ‘Faassen’s Black’, *Albizia julibrissin* Durazz., *Styphnolobium japonicum* (L.) Schott, *Prunus serrulata* Lindl. ‘Kanzan’, *Picea pungens* Engelm., etc.

Table 1. Tree species in park Zaimov.

Species	Number of individuals	Percentage of participation	New planted trees	Aesthetic value of the species
Conifers	**283 (3)**	**24.4**	**24**	
Abies concolor (Gordon) Lindley	19 (2)	1.6	6	pce, e
Cedrus atlantica (Endl.) Manetti	2	0.2	-	e
Cedrus atlantica 'Glauca'	2	0.2	-	pce, e
Cedrus deodara (Roxb.) G.Don	13	1.1	3	e
Chamaecyparis lawsoniana (A. Murray) Parl.	3	0.3	-	e
Picea abies(L.) H. Karst	60	5.2	-	e
Picea omorika (Pančić) Purk.	5	0.4	-	e
Picea pungens Engelm.	95 (1)	8.2	11	e
Picea pungens Engelm. 'Glauca'	8	0.7	-	pce, e
Pinus nigra J.F.Arnold	15	1.3	1	e
Pinus strobus L.	11	1.0	3	e
Taxus baccata L.	4	0.3	-	e, ob
Platycladus orientalis L.	47	4.1	-	e
Broadleaves	**874 (29)**	**75.6**	**135 (16)**	
Acer campestre L.	1	0.1	-	ace
Acer platanoides L.	162 (3)	14.0	6 (1)	ace
Acer platanoides 'Faasens.Black'	12 (5)	1.0	12 (5)	pce
Acer pseudoplatanus L.	10	0.9	5	ace
Acer pseudoplatanus L. 'purpurea'	1	0.1	-	pce, ace
Acer saccharinum L.	3	0.3	-	ace
Aesculus hippocastanum L.	66 (2)	5.7	3	ff
Ailanthus altissima Mill.	11 (2)	1.0	-	ff, ace
Albizia julibrissin Durazz.	11	1.0	11	ff
Betula pendula Roth	52 (3)	4.5	-	ace, ob
Catalpa bignonioides Walter	12	1.0	2	ff
Catalpa bignonioides Walter 'Nana'	1	0.1	1	ocf
Cotoneaster × watereri Exell	1	0.1		ff, ocf, e
Fraxinus exelsior L.	18	1.6	14	ace
Fraxinus ornus L.	2	0.2	-	ff, ace
Fraxinus angustifolia Vahl	145 (3)	12.5	3	ace
Fraxinus pensilvanica Marshall	82 (2)	7.1	-	ace
Juglans regia L.	3	0.3	-	
Lirodendron tulipifera L.	1	0.1	-	ace
Morus alba L.	6	0.5	-	
Morus alba L. 'Pendula'	2	0.2	-	ocf
Platanus x *acerifolia* (Aiton) Willd.	20	1.7	3	ace, ob
Populus alba L.	11 (1)	1.0	-	ace, pce, ob
Populus nigra L.	7	0.6	-	ace
Prunus avium L.	1	0.1	-	ff
Prunus cerasifera Ehrh.	16	1.4	-	ff
Prunus cerasifera Ehrh.'Atropurpurea'	4	0.3	-	ff, pce

Species	Number of individuals	Percentage of participation	New planted trees	Aesthetic value of the species
Prunus serrulata Lindl. 'Kanzan'	12 (2)	1.0	12 (2)	ff
Quercus petraea (Matt.) Liebl.	5 (2)	0.4	5 (2)	
Quercus robur L.	1	0.1		
Quercus robur L. 'Fastigiata'	5	0.4		ocf
Quercus rubra L.	20 (6)	1.7	18 (6)	ace
Robinia pseudoacacia L.	21 (1)	1.8	-	ff
Robinia pseudoacacia L. 'Umbraculifera'	6	0.5	-	ocf
Styphnolobium japonicum (L.) Schott	10	0.9	10	ff, ace
Sorbus torminalis (L.) Crantz	1	0.1	-	ace
Tilia cordata Mill.	120	10.4	15	ace
Tilia platyphyllus Scop.	8	0.7	6	ace
Tilia tomentosa Moench	1	0.1	1	ff, pce, ace
Ulmus laevis Pall.	3	0.3	-	ace

Note: in brackets the amount of dying or fully dead trees are shown; the aesthetic value of the species/cultivars with the suggested categories described in material and methods.

Shrub vegetation was not identified and mapped by single individuals, but on groups (vegetative volumes) (Fig. 2A). The following species were found in the park, with ornamental value in brackets: *Pinus mugo* Turra (e), *Juniperus × media* (e), *Berberis julianae* Schneid. (ff, ace), *Berberis thunbergii* DC. 'Atropurpurea' (ff, pce), *Cornus sanguinea* L. (ff, ob), *Deutzia scabra* Thunb. (ff), *Forsythia × intermedia* (ff), *Hybiscus syriacus* L. (ff), *Spiraea × vanhouttei* (ff), *Syringa vulgaris* L. (ff), *Ligustrum ovalifolium* Hassk., *Mahonia aquifolium* (Pursh) Nutt. (ff, ace, e), *Symphoricarpos albus* (L.) S.F.Blake (ff), *Prunus laurocerasus* L. (e), *Pyracantha coccinea* M.Roem. (ff, ace), *Rosa canina* L. (ff), *Rosa hybrida* (ff), *Ruscus aculeatus* L. (ff, e), *Sambucus nigra* L. (ff, ace).

The common species, used as alley trees when the park was built, were *Fraxinus angustifolia*, *Fraxinus pensilvanica, Acer platanoides, Tilia cordata, Aesculus hippocastanum* and *Betula pendula*. Silver birch trees had been planted in the central main axis, but only few of them are still standing and they are not in a very good condition. Big number of *Fraxinus pensilvanica* trees has been heavily pruned at some stage and their crowns are atypical. Knowing that the alley trees are the same age (approximately 60-years-old) and having big number of individuals from the other four species are prerequisites for calculation of the mean tree crowns parameters (Table 2).

There is no significant difference between the crown's parameters of Norway maple, Horse chestnut and Small-leaved lime mature trees in park conditions (Table 2, Fig. 3). *Fraxinus angustifolia* mean crown is around a meter taller and wider than the crown of the other three species (Table 2). Norway maple trees are smaller in height in park conditions (12.67 m) (Table 2) than in the forest (from 18.5 to 27 m in different stands) (Tomov et al. 2014). However, the mean trunk diameter of the park trees is 35.75 ±1.25 cm, which is a lot more than any of 50+ year-old forest stands (ranging from 18 to 30 cm) and is only 22 % less than the 120-year-old

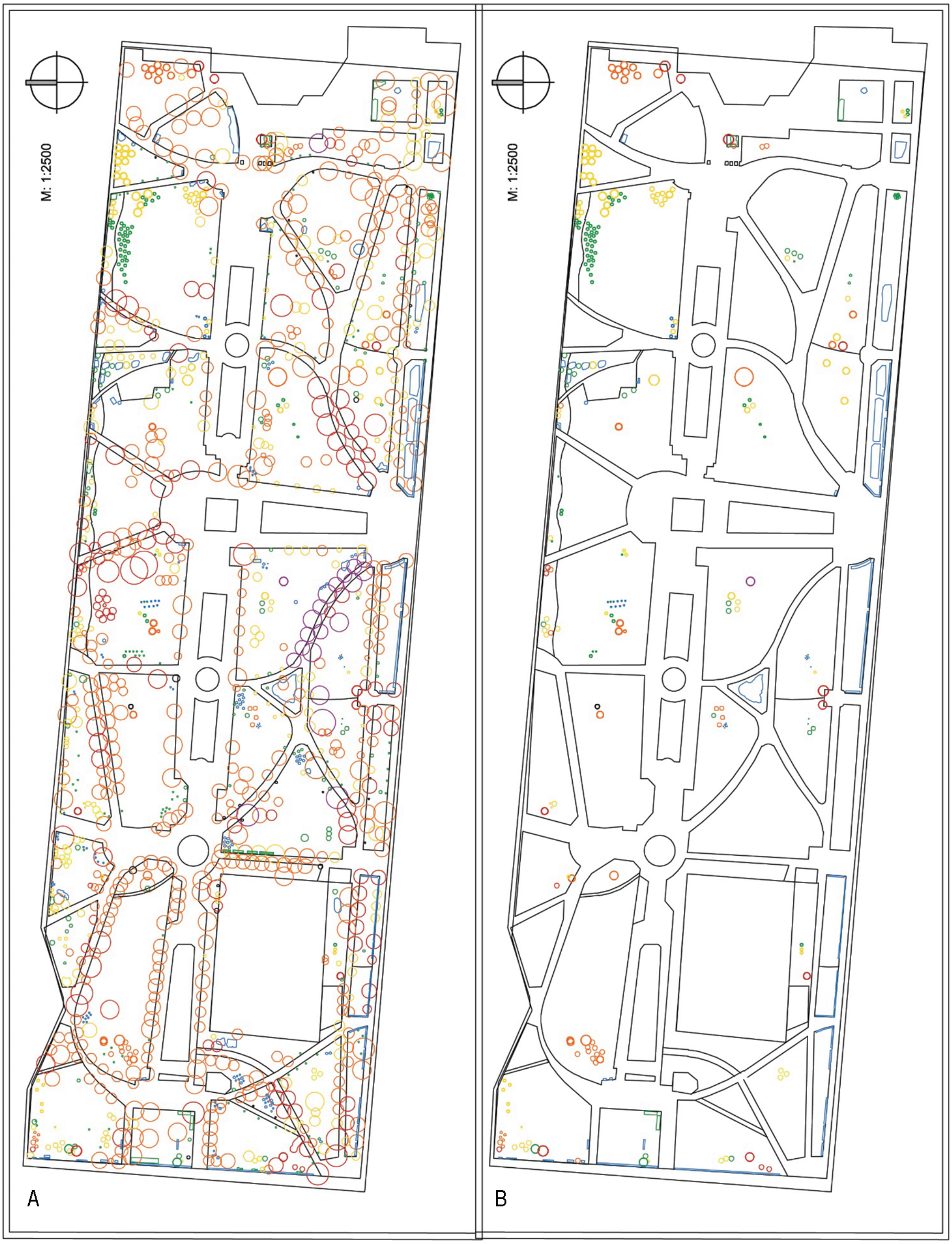

Fig. 2. Map of vegetation volumes in park Zaimov: A – growing season, B – winter.

Note: vegetation height: blue – 0–2 m, green – 2–5 m, yellow – 5–10 m, orange – 10–15 m, red – 15–20 m, purple – 20–25 m; dead plants are marked with black.

forest stand. That shows that the difference in the crown is not a result of worse conditions in the urban territory, but it is due to the low competition for light in less denser groups in the park. The same tendency was revealed for the *Tilia cordata* mean parameters. The trees are higher (22 ±4 m) in forest stands with smaller diameter (22 ±9 cm) (Hagemeier and Leuscher 2019) compared to those in the park: 12.85 ±0.22 m height and 40.42 ±1.67 cm DBH (Table 2).

Table 2. Parameters of four common species in park Zaimov.

Species (number of trees)	Trunk diameter (DBH), cm	Tree height, m	Crown diameter, m	Crown height, m
Acer platanoides (136)	35.75 ±1.25 a	12.67 ±0.15 a	7.51 ±0.14 a	10.01 ±0.17 a
Aesculus hippocastanum (57)	46.44 ±2.79 b	12.65 ±0.18 a	7.56 ±0.24 a	10.19 ±0.21 a
Fraxinus angustifolia (92)	47.45 ±4.08 b	14.16 ±0.23 b	8.70 ±0.23 b	11.26 ±0.26 b
Tilia cordata (63)	40.42 ±1.67 ab	12.85 ±0.22 a	7.12 ±0.23 a	10.28 ±0.21 a

Note: mean values ± standard error of mean, followed by the same letter are not significantly different with level of significance ($p \leq 0.05$).

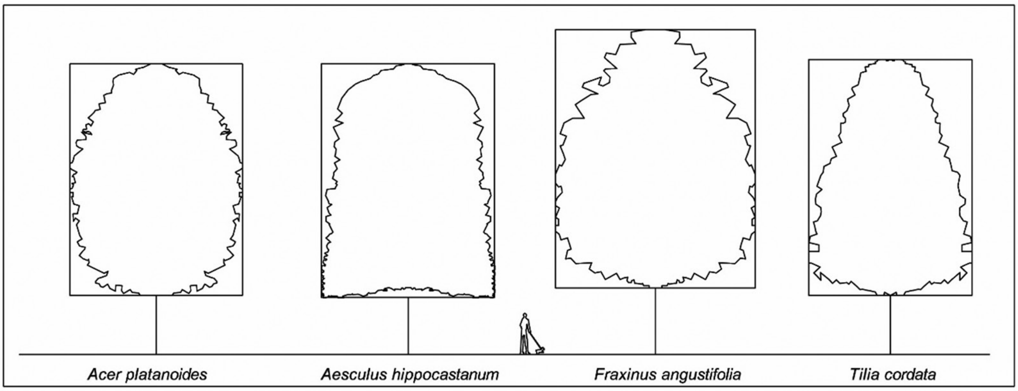

Fig. 3. Model of tree crowns of four common species at 60 years, M 1:200.

Furthermore, these trees presented a genetic reservoir of mature well-adapted to urban environment genotypes of the species. They could be investigated thoroughly as a breading material.

In general, the ornamental diversity within the park is high enough, with different effects nearly all the year round. Reasonably there aren't any long perspective views in park of that size, but still some close and middle range perspectives, with nice colour and texture contrasts, are revealed. Adding the seasonal flowers which are planted regularly in the central parterres, there is plenty of eye-catching vegetation. Each recreational environment requires a correct accent saturation rate for optimal aesthetic effect (Galev 2016), so planting more and more ornamentals without consulting a professional is controversial. However, more shrubs are needed to separates the spaces a little bit, adding fluence to the vertical transition from the lawns to the tree canopy, but above all to provide the needed border isolation from main boulevards.

Vegetation health status

Most of the vegetation (82.8 %) is in good health status (scoring 0 or 1). Some old alley trees (mostly from *Betula pendula*) inside the park are in bad condition (2 to 4) due to the species' relatively short life span. That shouldn't be big concern and they will be flowingly replaced if the right park maintenance applied. There are two bad tendencies though. The vegetation in the south part of the park adjacent to Yanko Sakuzov Blvd. suffers from the negative influence of the intense car traffic. Furthermore, big part of the old alley trees in that border part is missing (probably removed because of poor condition and potential threat) as it can be seen on the map (Fig. 2A). All this means that the border vegetation doesn't fulfil its main function, to provide isolation to the inside park areas. The hedge, mainly from *Ligustrum ovalifolium*, has been kept very short and barely does any good in that direction. The other bad tendency is that big percentage of the new planted trees is either already dead or suffering (mostly from droughts in the summer and lack of watering). That is something common to the whole city and is very big problem concerning a whole bunch of institutions and reflects negatively to the citizens' both health and financial status.

Crown parameters and ecological aspect

Conifers are usually with high density crowns but due to self-pruning or bad condition 37 individuals were defined with sparse crown, 139 were considered with medium crown density and 104 – with dense crown. The broadleaves were spread as follows: 116 – sparse, 691 – medium, 38 – dense. The whole REV of the tree vegetation was 79,511.45 m^3. With park area of 102,000 m^2 it indicates 0.8 m^3 mean REV of vegetation per square meter. That number could allow comparisons with other green areas, if the method is applied in future researches. Tree oxygen production varies by tree size and many more different factors, but according to the algorithm of Nowak et al. (2007), it can be presented as a function of the tree trunk diameter (DBH). Based on data from Minneapolis, Minnesota (Nowak et al. 2006) it had been calculated that trees 2.54 to 7.62 DBH produced ≈2.9 kg O_2/year, trees 22.86 – 30.48 DBH: 22.6 kg O_2/year, 45.72 – 53.34 DBH: 45.6 kg O_2/year; 68.58 – 76.2 DBH: 91.1 kg O_2/year, and greater than 76.2 DBH: 110.3 kg O_2/year (Nowak et al. 2007). Calculating with those ratios, park Zaimov is producing 29,282.04 kg of net oxygen (produced O_2 – consumed O_2) annually. In other terms 1 m^3 REV produces 0.37 kg of oxygen on a yearly basis. In that way REV can be used instead of DBH for future researches where vegetation is denser and the individual trees can't be measured. Just for better understanding the ecological value of the vegetation, it needs to be said that, according to Perry and LeVan (2003) an average adult human oxygen consumption rate is 0.84 kg/day.

Only around 10 % (7520.55 m^3) of the REV was made by conifers (Fig. 2B), which roughly means that during winter, when the air pollution problem is worst, the capacity of the park vegetation to absorb dirt and CO_2 and produce oxygen is reduced 10 times. It is fair to say that the percentage of conifer individual trees (24.4 %) is adequate, but more than 2/3 of them are planted in the past 20 years (24 young new planted trees and 169 – younger than 20 years) (Fig. 4).

Fig. 4. Park Zaimov nowadays, seen from the residential buildings.

The most planted conifer species has been *Picea pungens* (Fig. 4), which has good tolerance to dry and polluted air and must be preferred to *Picea abies*. The Norway spruce needs moist fresh air, which automatically means that those 60 individuals in the park are already suffering or will suffer at some stage. The placement of the evergreen vegetation is also an issue, because in the borderline adjacent to the most intense traffic there isn't any evergreen vegetation, except one big patch of *Mahonia aquifolium*, which for some unknown reason has been kept as low as half a meter tall. The other exception is a group of *Platycladus orientalis* trees planted under the canopy and had never been pruned. As a result, they don't fulfil their aesthetic targets, neither the ecological ones. More evergreen shrubs and trees planting needs to be considered in future reconstructions of the park, as a barrier against air and noise pollution mainly from south. These will raise the REV during winter and in general, and will make the inside of the park more suitable for visitors.

The highest tree in the park is 22 m tall *Quercus robur* 'Fastigiata' individual, followed by a pack of ash trees around 20 m. In long terms a higher multilevel canopy in some areas of the park could be targeted by planting suitable tree species.

Conclusions

Vegetation in park Zaimov is generally well planned and contains a lot of valuable trees from common park species in good condition, at age of around 60 years. It needs to be well preserved in the future.

More vegetation needs to be added, in places where the old one has been removed or impend to be, due to conditional reasons. These needs to be done fluently and according to the vision of landscape architects. It is highly recommended to build higher and denser hedge barrier of evergreen vegetation across the south border of the park.

More intensive post planting maintenance is needed for the new planted vegetation to survive and develop.

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