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A TELEPÍTÉSI SŰRŰSÉG ÉS A LOMBKORONA-BORÍTOTTSÁG VIZSGÁLATA BUDAPESTI SZABADTEREKEN

Esettanulmányok 2. rész – Szent Gellért tér

STUDY OF PLANTING DENSITY AND CANOPY COVER IN OPEN SPACES IN BUDAPEST

Case Studies Part 2 – St Gellért Square

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ABSZTRAKT

A városi zöldfelületek rendszerében kulcsszerepet töltenek be a közterületen álló fák, amelyeknek egyre nagyobb kihívásokkal kell szembenézniük az urbanizáció, a klímaváltozás és az emberi beavatkozások hatásai miatt. A zöldterületek jelentősen javítják a mikroklímát, támogatják a biológiai sokféleség megőrzését, és esztétikai értékük is jelentős, ezért védelmük és fejlesztésük kiemelten fontos. Kutatásunk a budapesti szabadterek lombkorona-fedettségét értékeli a telepítési sűrűség függvényében, különös figyelemmel a terek és utcák fás szárú növényeinek telepítési távolságára és az ebből adódó borítottsági értékek összehasonlítására. Vizsgálataink során figyelembe vettük a telepítéskori, jelenkori és a teljesen kifejlett lombkorona arányának mennyiségi és minőségi változásait, hogy az egyes fafajok igényeit és sajátosságait (koronaforma, növekedési erély) figyelembe véve ideális telepítési ajánlásokat fogalmazhassunk meg. Második esettanulmányunk során a Szent Gellért tér faállományát vizsgáltuk. Az értékelés során megállapítottuk, hogy a lineáris facsoportok egyedei – taxontól függetlenül – habitusuk, lombkoronaformájuk és telepítési sűrűségük alapján közel ideális feltételek mellett fejlődnek, és várhatóan a jövőben is jól fejlődhetnek. Ezzel szemben a zöldkazettákban álló fák közül elsősorban a facsoport külső egyedei bizonyulnak hosszú távon is értékesnek az ökoszisztéma-szolgáltatások szempontjából. A jelenlegi nyílt lombfelületek aránya 97%, amely a vizsgált szabadterek között a legjobb értékek közé tartozik, azonban a fák kifejlett korában a zöldkazettában ez az arány 52%-ra, míg a lineárisan ültetett facsoportok esetében 71%-ra esik vissza, ezért kijelenthető, hogy a zöldkazettákban álló taxonok a rossz telepítési sűrűség következtében jelentősen akadályozni fogják egymás fejlődését, és kedvező hatásaikat sem képesek teljes mértékben kifejteni majd a jövőben.

Kulcsszavak: városfásítás, fasorok, lombkorona-borítottság, telepítési sűrűség

Table 1: Case study sites

Közterület neve / *Name of the public area*	**Elhelyezkedés / *Location***	**Kiterjedés / *Size***	**Zöldfelület-borítottság / *Green space coverage***	**Fák száma / *Number of trees***
Móricz Zsigmond körtér/ *Móricz Zsigmond Square*	XI. kerület / *11th district*	11.200 m²	1380 m²	76 db
Szent Gellért tér / *St. Gellért Square*	XI. kerület / *11th district*	5300 m²	1760 m²	32 db
Széll Kálmán tér / *Széll Kálmán Square*	II., XII. kerület / *2nd, 12th district*	21.000 m²	3450 m²	112 db
Olimpiai park / *Olimpia park*	V. kerület / *5th district*	8100 m²	6425 m²	44 db
Podmaniczky Frigyes tér / *Podmaniczky Frigyes Square*	V. kerület / *5th district*	4700 m²	750 m²	60 db
Fővám tér / *Fővám Square*	IX. kerület / *9th district*	5300 m²	740 m²	38 db

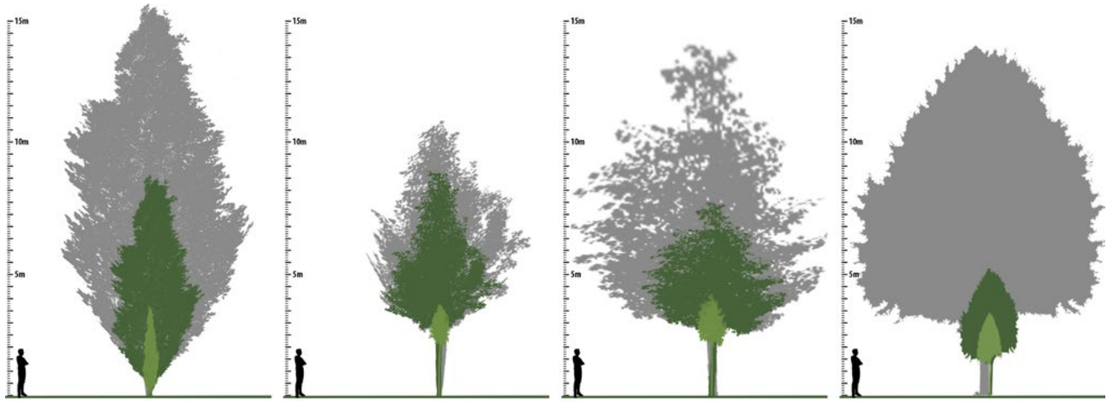
ABSTRACT

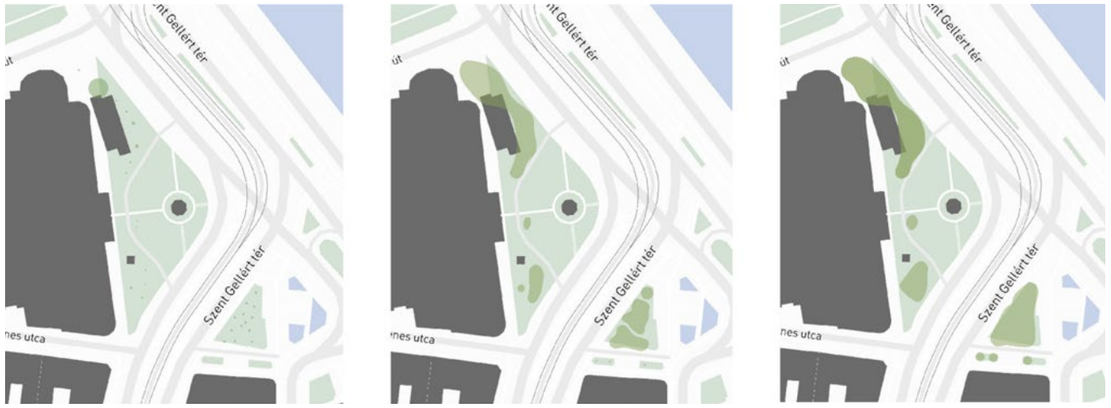
Trees in public places have a key role in the urban green space system and are facing increasing challenges due to urbanisation, climate change and human interventions. Green spaces significantly improve the microclimate, support biodiversity conservation and have significant aesthetic value, which makes their protection and enhancement a priority. Our study assesses the canopy cover of open spaces in Budapest as a function of planting density, with a special focus on the planting distance of woody plants in open spaces and streets, to compare the resulting cover values. Our studies have taken into account quantitative and qualitative variations in the proportion of canopy at the time of planting, at the present time and at full maturity, in order to formulate ideal planting recommendations taking into account the needs and characteristics (crown shape, growth vigour) of each tree species. Our second case study focused on the tree population of St Gellért Square. The assessment showed that the specimens of linear tree groups, regardless of taxon, are growing under near ideal conditions in terms of habit, canopy shape and planting density, and are expected to continue to grow well in the future. In contrast, the trees in green cassettes are mainly the outer ones of the tree group, which are of long-term value for ecosystem services. The current open canopy cover of 97% is among the highest of the open spaces studied, but this falls to 52% in the green cassette and 71% in the linear planted tree groups when the trees reach maturity, suggesting that the green cassette species will significantly impede each other's development due to poor planting density and will not be able to fully develop their beneficial effects in the future.

Keywords: urban forestry, allées, tree canopy cover, planting density

1.INTRODUCTION

The role of urban trees has been increasing in the context of urbanisation and climate change, as they contribute to heat island effect reduction, microclimate regulation and air filtration, while their root systems improve soil structure, reduce erosion [1-3] and increase social interaction [4-7], while they have recreational and cultural [7-9] value. At the same time, trees in urban environments have difficulty in adapting to increased human activity and the





◂◂**Fig. 1:** Habits of the dominant taxa of St. Gellért Square at planting, present day and maturity: 1) Quercus robur 'Fastigiata', 2) Malus tchonoskii 'Belmonte', 3) Corylus colurna, 4) Tilia platyphyllos
◂◂**Fig. 2:** Canopy cover changes in St Gellért Square at the time of renovation (1%), currently (17%) and when the trees reached maturity (23%)
Table 2: Assessment of the woody taxa of St. Gellért Square according to their growth vigour

Taxonok / *Taxa*	**Telepítés éve / *Year of planting***	**Lombkorona átmérő* 2023-ban (m) / *Crown diameter* in 2023 (m)***	**Schmidt-féle koronaforma/ *Cronw shape according to Schmidt [24]***	**Schmidt-féle növekedési erély / *Growth potential according to Schmidt [24]***	**Átlagos növekedési tényező / *Average growth factor***	**Növekedési erély a Szent Gellért téren / *Growth vigour on the St. Gellért Square***
Acer negundo	1980	14,8	Tojás / *Oval*	Gyors / *Fast*	0,4	Átlagos / *Average*
Chamaecyparis lawsoniana cv.	2003	3,2	Kúp / *Conical*	Átlagos / *Average*	0,3	Átlagos / *Average*
Corylus colurna	2003	9,4	Tojás / *Oval*	Átlagos / *Average*	0,3	Átlagos / *Average*
Fraxinus ornus	2003	7,3	Tojás / *Oval*	Lassú / *Slow*	0,4	Átlagos / *Average*
Malus tchonoskii 'Belmonte'	2003	5,3	Tojás / *Oval*	Átlagos / *Average*	0,3	Átlagos / *Average*
Prunus × eminens 'Umbraculifera'	2023	1,2	Gömb / *Round*	Átlagos / *Average*	0,2	Lassú / *Slow*
Quercus robur 'Fastigiata'	2003	4,8	Oszlop / *Columnar*	Átlagos / *Average*	0,3	Átlagos / *Average*
Tilia platyphyllos	2003	5	Tojás / *Oval*	Átlagos / *Average*	0,2	Lassú / *Slow*

* a vizsgált egyedek aktuális koronaátmérő adatok átlaga alapján / * *based on the average of the actual crown diameter data of the studied specimens*

consequences of global climate change [10]. The quality and quantity of green spaces are degraded by urban development, including the growth of covered surfaces and vehicular traffic [2,3,11]. In addition, the life span of urban trees is significantly shorter than in natural environments, making the preservation and enhancement of green spaces a priority for the future [12-16].

The ecosystem services provided by urban trees can be divided into four main categories: provisioning, regulating, supporting and cultural services [17]. International studies have investigated different aspects of ecosystem services, including the energy-saving potential of urban trees and the use of allometric equations to estimate canopy size [18-22].

Our research aims to explore the problems of urban tree planting and to determine the ideal planting distances for different taxa in order to maximise the climatic, ecological and aesthetic benefits of the canopy.

2.METHODS

Our studies were conducted at individual level in the major open spaces of Budapest and their directly connected tree-lined areas (Table 1).

We assessed the woody taxa in the open spaces at three different times: when the square was renovated, in its current state, and when the taxa had reached their adult size.

For the 2011 data on "growth vigour" [24] by Gábor Schmidt, several values were identified that needed further clarification, so a growth factor was calculated from the variable tree dimensions (crown diameter/canopy volume) and age, and the taxa were redefined according to their growth vigour. To define mature canopy cover, we introduced a "growth Factor" based on the taxa's development to date, which can be slow (0-0.2), average (0.3-0.5) and fast (0.6>) [23,25].

$$\text{Growth factor} = \frac{\left(\frac{\text{current size of the canopy}}{\text{canopy size at planting}}\right)}{\text{age of the tree}}$$

Based on the calculations, we have identified free (green in the figures), partially overlapping (yellow) and significantly overlapping (red) crown categories for the individuals studied. In terms of overlapping, an important difference was that we recorded the overlapping of the crowns of two different specimens as partially overlapping (yellow), while more than two specimens were defined as significantly overlapping (red). The asymmetry and crown distortions caused by buildings were also represented with red. All these indicate which individuals have a less than ideal distance from the planting site or buildings which leads to an underdeveloped character and limited growth over time [23].

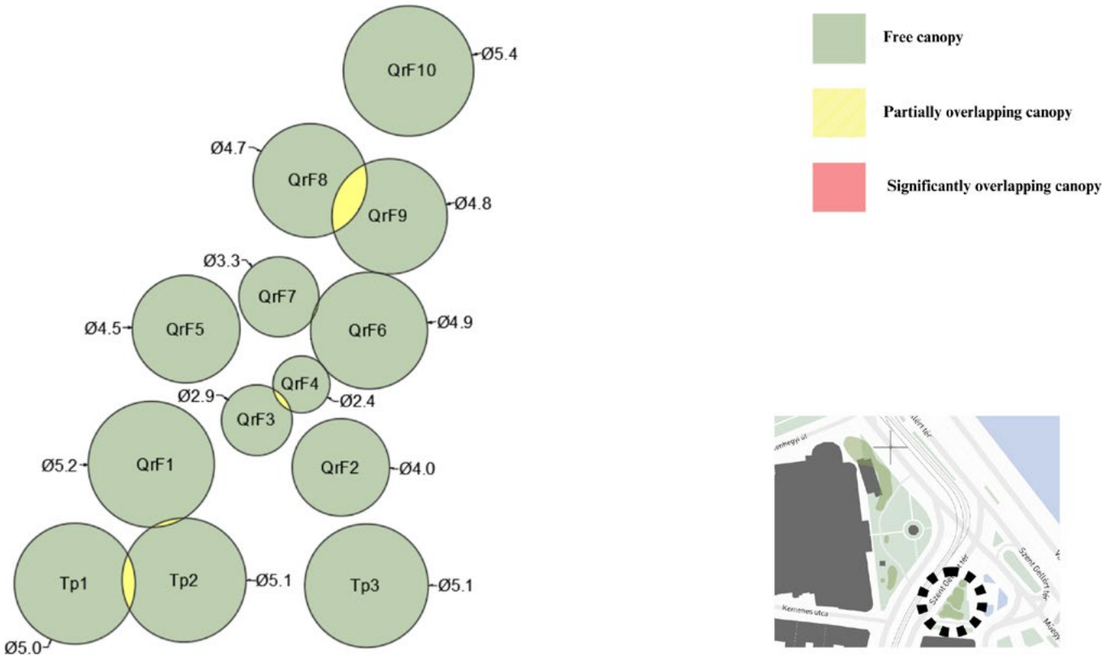
The second site of our research is St. Gellért Square, which, like Móricz Zsigmond Square, is located in the 11th district of Budapest. The square has been landscaped since 1952 and was last renovated in 2003. From an urban and environmental point of view, it is a very varied square, as the Danube and the Gellért Hill determine the microclimatic conditions to a large extent, while the metro line 4 and the surface tram and bus transport put a heavy strain on the green spaces [26,27].

3. RESULTS

A total of 28 woody specimens belonging to 8 different taxa were found in St Gellért Square. Pyramid oaks (*Quercus robur* 'Fastigiata') are dominant, with 10 specimens. The habit of the trees identifies three types of crowns: columnar, globular and flattened conical (Fig. 1). All 28 trees are located in green areas. The exact date of the planting of the old green maple *(Acer negundo)* is unknown, but it is assumed that it was planted in the 1980s at the north-east corner of the Gellért Hotel. In 2024, two American tulip trees *(Liriodendron tulipifera)* were planted in the green box next to the metro station, but they died due to the dry summer. The trees in the green cassette next to the metro are 3 to 5 metres apart, while the trees in the arched planting in front of the Gellért Hotel are 5 to 6 metres apart. Their distance from the buildings is 7-8 metres, which does not hinder their growth [23].

3.1. Canopy cover assessment

In order to define the canopy cover in the future, the growth vigour of taxa was investigated. The revised growth factor showed that most taxa in St Gellért Square grow more slowly than the values of Schmidt. The large-leaved linden *(Tilia platyphyllos)* and the dwarf sour cherry (*Prunus × eminens* 'Umbraculifera'), considered to be of 'average' growth, show 'slow' growth in this environment, while the green maple *(Acer negundo),* classified as 'fast',



and the flowering ash *(Fraxinus ornus),* considered to be 'slow', both show 'average' growth rates. The growth rates of Tschonoskii apple (*Malus tchonoskii* 'Belmonte'), Turkish hazel *(Corylus colurna),* pyramid oak (*Quercus robur* 'Fastigiata') and Oregon false cypress (*Chamaecyparis lawsoniana* cv.) are in line with those of Schmidt (Table 2).

Since the renovation in 2003, the pyramidal oaks (*Quercus robur* 'Fastigiata') in green cassettes have become the dominant feature on the eastern side of the square. However, we observed significant differences in size between the specimens: the canopies of the trees at the edge of the group is much more developed than those of their counterparts in the interior, which have less space and are in a shadier environment. Differences in height of up to 2–2.5 m were observed, while differences in crown width of up to 3 m were noted. The growth and vigour of linden trees in green cassettes is significantly below that of the other species. Their crowns are dry and their vigour is below that of an average 20-year-old large-leaved linden. In contrast, no significant differences were observed in the specimens of Tchonoskii apples (*Malus tchonoskii* 'Belmonte') and Turkish hazel (Corylus colurna) in front of the hotel.

When canopy cover was examined, it was found that the Turkish hazel, which currently provides high shade, would be the taxon with the largest canopy cover. The current canopy cover of the 5300 m² square is 903 m², while it is assumed that the canopy cover will be more than 1200 m² when the trees are mature, resulting in an overall canopy cover of 23% (Figure 2) [23].

3.2. DETAILED ANALYSIS OF TREE GROUPS

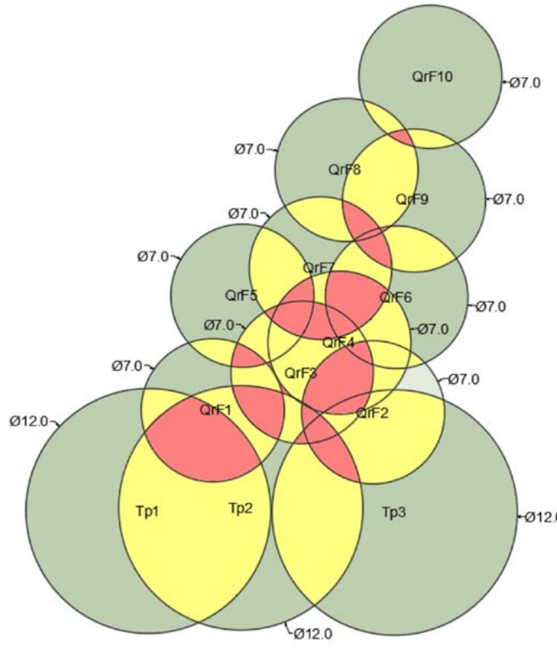
In the detailed analysis, three groups of trees with different compositional roles and different taxa were examined.

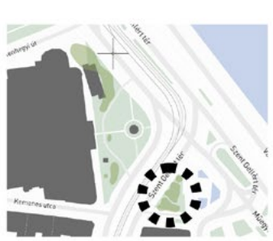
3.2.1 Study of tree specimens in the green cassette

A total of 13 specimens of two taxa are found in the 376 m² central green box on the eastern side of the square. Of the trees found here, seven of the columnar oaks are larger (4.5 m>) and three are smaller (<3.5 m), while three of the large-leaved lime trees are nearly the same size (5 m) (Fig. 3).

Although 13 trees may seem like a lot in the green space, the oaks have a high proportion of open canopy

Fig. 3.a-b: Canopy assessment of a tree group in the green cassette in its current and predicted mature state
Fig. 4: Canopy assessment of a group of trees in the green cassette in the current and mature state





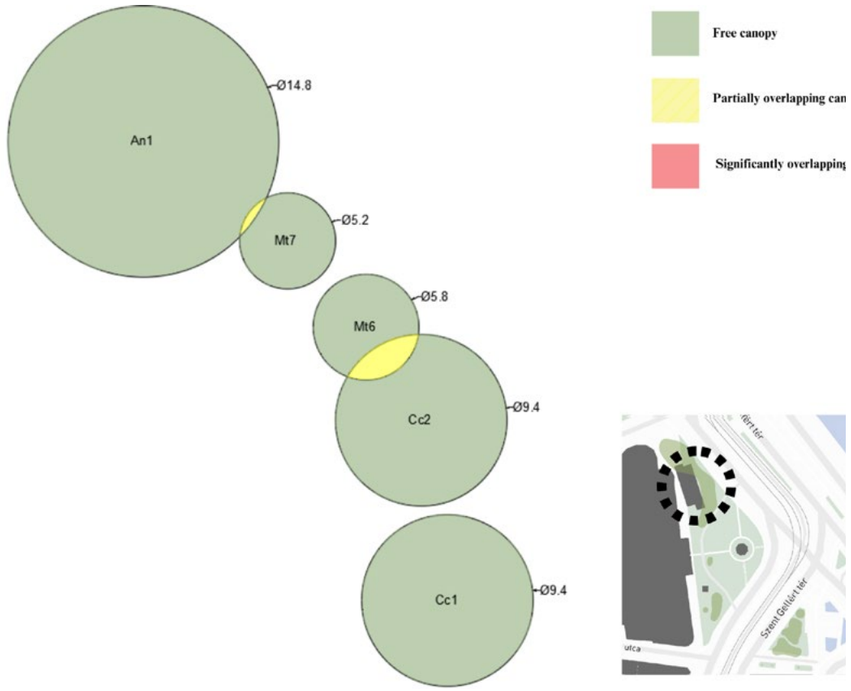
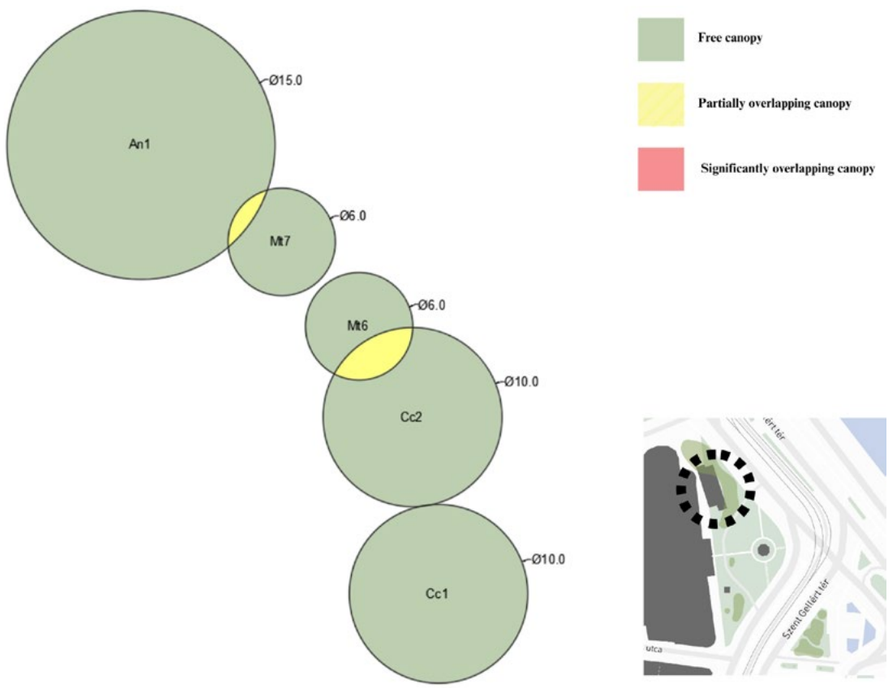


Fig. 5.a-b: Canopy assessment of the group of trees in front of the Gellért Hotel in their current and predicted mature state



even when planted close together. Currently, five out of ten have partial overlap, averaging only 0.8 m². A similar result is observed for linden trees, where the average overlap is 1.2 m². The overall results show that 96% of the canopy of the tree groups is growing free, while the partially overlapping area is 4%, and no significant overlap was observed in any of the crowns (Figure 4).

If all specimens reach their assumed adult size in the future, the expected results are less favourable. The percentage of useful canopy area will drop from 96% to only 32%, while the percentage of partially overlapping crowns will increase to 41% on average. The largest change is in the proportion of significantly overlapping crowns, where almost one third (28%) of the total crowns will be in this category. The most noticeable change in canopy cover will be observed in the oaks near the lime trees. These oaks have an average free canopy area of 4.5 m². Even worse ratios are obtained for the inner specimens of the oak group, where more than half of the canopy will be significantly overlapping. The columnar habit improves the proportions slightly, but it can be concluded that only the upper quarter of the canopy area will be aesthetically and ecologically valuable.

The oaks in the northern part of the green cassette have a large amount of open canopy even at maturity, so their beneficial effects will be significant. In contrast, the proportion of partially overlapping canopies is on average 50% for linden trees [23].

3.2.2. The group of trees in front of the Gellért Hotel

The detailed study of the northern section of the hotel found two Turkish hazel *(Corylus colurna),* two Tschonoski apple (*Malus tschonoskii* 'Belmonte') and an old green maple *(Acer negundo).* The specimens were planted at a spacing of 6–9 m, which is ideal for both current and mature size. The largest tree in the group is a green maple with a crown 14.8 metres in diameter. Among the younger trees, the apple and hazel trees are also growing ideally, with crowns that are typical of the taxon and are ecologically and aesthetically outstanding (Figure 5).

The planted taxa have and will have significant useful canopy area. The apple trees, which have an upward branching system, show a slight overlap with the broader habit hazel and maple trees around them. Due to the linear planting, no significant overlapping crowns have developed in either the current or mature state. Currently, the proportion of open, free canopy cover averages 94% for the five individuals. Today, only one of the ornamental apples is overlain by part of the foliage of the nearby hazel. As the specimens in the urban environment are almost mature, the proportions will not change significantly in the future. The open foliage is expected to decrease by only 5%, while the percentage of partially overlapping surfaces will average around 11% (Figure 6).

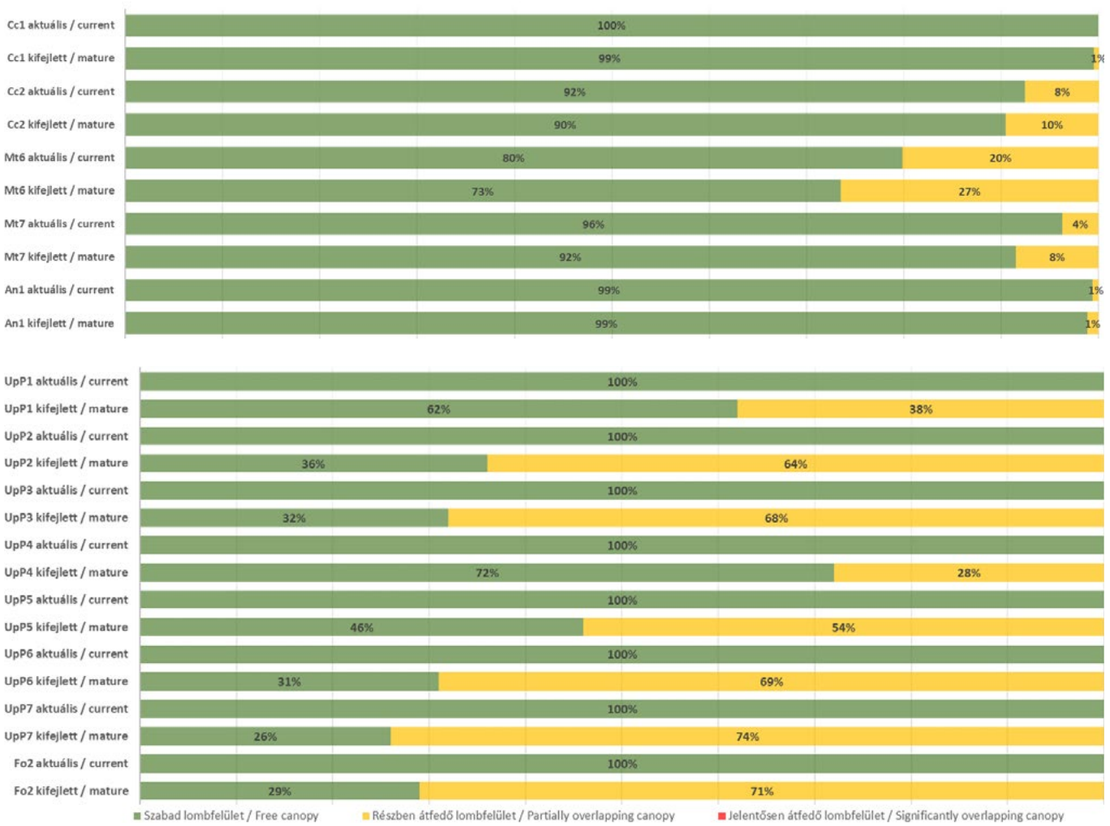
3.2.3 Assessment of the St Gellért embankment facies specimens

The longitudinal part of the St. Gellért embankment is taxonomically diverse. Flowering ash *(Fraxinus ornus),* field maple *(Acer campestre),* common ash *(Fraxinus excelsior),* hybrid cockspur thorn (*Crataegus × lavallei* 'Carrierei'), American hackberry *(Celtis occidentalis),* Russian olive *(Elaeagnus angustifolia)* and Siberian elm (*Ulmus pumila* 'Puszta') were planted.

We have analysed specimens from the embankment section directly adjacent to St Gellért Square, where seven elms (*Ulmus pumila* 'Puszta') and one flowering ash *(Fraxinus ornus)* are found. Specimens were generally planted at a distance of 6–7 m, but in case of vacant tree sites or disturbing infrastructure, this distance can exceed 10 m. An examination of their current condition shows that although they are not ideal from an aesthetic and health point of view, their existing canopy is fully beneficial in ecological terms, with all eight specimens having 100% free canopy cover. The elms grow a broad crown, so significant crown overlap can be expected when mature. The current 100% open canopy cover will decrease to 44%, while the proportion of partially overlapping crowns will increase to 56% on average. As the Siberian elm has a nearly horizontal branch system, the overlapping crowns do not significantly interfere with each other. The free canopy area percentage of flowering ash falls back to less than one third at maturity, and it is not able to compensate for these parts in terms of habit (Figure 7) [23].

4. DISCUSSION

The assessment of the woody vegetation of St Gellért Square and St Gellért Embankment showed relatively positive results, especially in terms of canopy cover. When looking at the canopy cover, it is important to note that the heavy rail and vehicle traffic through St Gellért Square



breaks up the entire square for a considerable distance. If we take the open space area – 3509 m² – instead of the actual area, the canopy cover is 26%, which is within the ideal range (25–30%) [28].

Careful analysis of the planting distances showed that the tree spacing correctly reflects the space requirements of each taxon. As a result, the current canopy cover is extremely high at 97%, one of the best values among the open spaces studied. However, it should be noted that this percentage will decrease to 52% as the trees mature, mainly due to the dense planting of the green cassettes, as the proportion of open canopy in the linearly planted tree groups decreases to 71%. Partially overlapping and significantly overlapping crowns will naturally increase as they grow, from the current 4% to 45% and from 0% to 20% of the total, respectively.

The overall assessment shows that individuals in linear tree groups, regardless of taxon, are and can be expected to continue to develop in a near-ideal way in terms of habit-canopy form-planting density, while among the trees in green boxes, it is mainly the oaks on the outer edge of the group and the globe oaks that can be of real long-term benefit in terms of ecosystem services, while the crowns of the currently undeveloped lime and interior oaks are largely dominated by the trees surrounding them. ⦿

Fig. 6: Canopy assessment of the tree group in front of the Gellért Hotel in its current and predicted mature size
Fig. 7: Canopy assessment of the St Gellért embankment canopy in its current and predicted mature state

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