Identifying Drivers of Increasing Tree Density in Urban Parks

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Abstract

Urban trees have become a major topic in both professional and public discussion over the past decades. Tree planting programs are a popular tool for increasing urban green surfaces and they are often pushed by policymakers in large cities (Eisenman et al. 2024). In areas with limited tree cover, newly planted trees can increase the quality of life significantly (Cavalieri and Konijnendijk 2024). On the other hand, in the case of urban green areas with existing canopy cover, planting new trees is often unnecessary or even counterproductive, as it can negatively affect visual connections, spatial structure or the visibility of existing valuable trees (Pretzsch et al. 2015). In many parks and other urban green areas, tree cover can be observed to increase significantly over time by spontaneous processes (EEA 2021), which is an important aspect of urban green space planning. Current advances in modeling tree growth help predicting future changes in canopy cover, but not all possible factors are taken into consideration in available models.

In our research, we identified and analyzed factors behind the increasing tree density through the example of several urban green areas in Budapest, Hungary, using fieldwork, historical and current aerial and satellite images. The changing canopy size of individual trees was tracked through series of photographs, and each tree was identified and surveyed using on-field methods as well. We compared actual canopy increase with expected growth predicted by tree growth models. We concluded that certain drivers of tree density increase, such as the appearance of seedlings, are not included in such models, limiting their use in certain green area types. We also studied the changes the increased tree density causes to the spatial structure, diversity, maintenance and use of these parks and the resulting practical consequences. Our results show that in parks and green areas, tree density can increase spontaneously even without new trees being planted, which implies that a paradigm change is necessary in urban tree planting programs.

Introduction

Recent years have seen a shift in public opinion and policy regarding urban green areas and especially trees. Tree planting programs have become widespread tools to mitigate negative effects of the urban environment, including air pollution, urban heat islands and loss of biodiversity. However, in green areas with existing tree cover and community functions, excessive planting of new individuals can be counterproductive, negatively impacting functionality, visual connections and spatial structure. In our research, we aim to identify and analyze processes behind increasing tree cover in several green areas in Budapest, Hungary, using aerial photographs and fieldwork. Comparing the projected increase of canopy cover of existing tree growth models and actual, measurable data, as well as inventorying current trees in the study areas can help identify factors that existing models do not take into consideration.

In our research, we seek answers to the following questions: (1) How did tree density and canopy cover change in past decades? (2) Can actual change be projected by using existing canopy growth calculation models? (3) What are the processes (other than the growth of individual trees) leading to the increase in tree density and canopy cover in the study areas?

Background and Literature Review

In recent years, guidelines for planting urban trees have changed significantly. While previously planners were primarily focusing on ornamental value – spectacular crown shape, habit, display of flower or fruits -, today ecological properties and potential ecosystem services of plants have become the most important factors (Rall, Kabisch, and Hansen 2015; Elderbrock et al. 2020; Eisenman et al. 2024; Semeraro, Scarano, and Pandey 2022; Cortinovis and Geneletti 2018, Ibes 2016). Vegetation plays a key role in regulating local climate and mitigating the Urban Heat Island effect, trees being the most effective vegetation type in that regard (Bolund and Hunhammar, 1999; Kapoor, 2017; Dimoudi and Nikolopoulou, 2003; Wang et al., 2018; Francini et al., 2022). Therefore, it is extremely important to create artificial urban ecosystems with the greatest possible potential for ecosystem services, reducing the ecological debt of cities and increasing their livability and climate resilience (Gómez-Baggethun and Barton 2013).

The ecosystem services of trees can be expressed by their environmental value, which is usually based on characteristics like canopy size and structure, foliage quality, texture, period of foliage etc. (Liang and Hunag 2023). Another important factor is age. Unfortunately, however, in urban environments trees cannot be expected to reach their natural taxon-specific maximum age, as most trees struggle to survive in cities where conditions are inhospitable and very different from their natural habitats. Regardless, different taxa have different growth rates, which creates a pattern in canopy cover even in urban spaces. Newly planted trees in areas with limited vegetation can significantly increase livability. In areas with limited tree cover, newly planted trees can increase the quality of life significantly (Cavalieri and Konijnendijk 2024). On the other hand, in the case of urban green areas with existing canopy cover, planting new trees is often unnecessary or even counterproductive, as it can negatively affect visual connections, spatial structure or the visibility of existing valuable trees (Pretzsch et al. 2015). In many parks and other urban green areas, tree cover can even be observed to increase significantly over time by spontaneous processes (EEA 2021).

Method and Data

In order to assess and analyze how and why canopy cover in urban areas has changed in past decades, we selected 3 study areas in District XI. (Újbuda) of Budapest (Figure 1). The selected areas are all stable green areas (the basic functions have not changed in the 35 years since the change of regimes) that are all publicly accessible and observable. The study areas are the following:

(1) **Törőcsik Mari Park** (widely known as Feneketlen-tavi park of "Lake Feneketlen Park"), a public park established between 1958 and 1960 around a clay mining lake. Currently one of the most popular and intensively used green areas in the Southwestern part of Budapest,

which includes a playground, an outdoor gym, a running track and an open-air theater (recently repurposed as a pub).

(2) A chain of small public green areas along the Southern side of **Etele Road** between Tétényi Road and Rátz László Street, located around and between housing blocks that were built between 1973 and 1975. The area is located next to a major road and has a high population. The green surfaces are mainly used for recreation and relaxation and also include a playground.

(3) **Albertfalva liget**, a public park between Fehérvári Road (a very busy major road) and the Fegyvernek Street housing estate, built between 1973 and 1978. Very intensively used by commuters and includes a playground, several separate play structures and a concrete football/basketball court.

Figure 1. Location of the study areas in the 11th district of Budapest, Hungary (mapbox.com)

To determine the extent of change in canopy cover, we analyzed aerial photographs taken at different points in time. Georeferenced historical aerial photos were acquired from the webpage geoshop.hu. The changes in tree density were determined by comparing three points in time: 1990; 2000 and 2022. The use of earlier photographs would have resulted in flawed conclusions as the bulk of the vegetation of the study areas was replanted in the late 1980s, with a high number of young trees visible on the 1990 photographs, particularly in the Albertfalva liget and Etele Rd. areas. Canopy-cover was measured for the entire study areas. In this phase of the research, we identified overall changes in tree cover, which may include the growth of existing trees, removal of entire individual trees or major parts of their canopy, as well as the appearance of new trees.

From a landscape architectural point of view, there are several existing methods aiming to define the expected change in canopy cover, one of the most important design aspects from an aesthetic and public safety perspective. In Hungary, ideal canopy cover is considered to be between 25-30% for public open spaces and between 40-60% for parks (Városklíma Műhely 2011).We delineated smaller sub-areas where individual trees are clearly identifiable on the 1990 aerial photograph to determine whether existing tree growth models can be used to predict tree cover changes in public urban situations (Quigley 2004; McHale et al. 2009; Schmidt 2003; Tóth 2024; Tóth, Doma-Tarcsányi, and Szabó 2024). Changes in tree density (number of individual plants) were analyzed in these same smaller parcels to avoid confusion in densely vegetated areas where individual plants cannot be identified without a doubt. The number of trees and the extent of their canopy cover was measured using AutoCAD 2024, while calculations were conducted using Microsoft Excel. In order to determine the drivers behind changes in tree density, we conducted field surveys in all study areas in November and December of 2024. On site, we surveyed individual trees identified as newly appearing in any of the aerial photographs as well as the overall vegetation structure and identified different processes behind the changes. Additionally, we studied the design and functions of the green areas to gain a better understanding about how the changes in canopy cover and tree density affect the usability and design of urban green spaces.

Results

Our results show that in all three study areas, canopy cover has increased markedly between 1990, 2000 and 2022. In the case of **Törőcsik Mari Park**, the green area with the most well-established vegetation in 1990, canopy cover increased from 33% (1990) to 40% by 2000, and it reached 44% by 2022. (Figure 2). clearly shows that several areas with previously open, grassy terrain have gradually transformed into a closed, wooded area.

Figure 2. Canopy cover study of Törőcsik Mari Park (Lake Feneketlen)

In the **Etele Rd.** area, the 11% canopy cover of 1990 increased to 52% and eventually to 63% by 2022, a drastic growth in shaded areas (Figure 3). The relatively small green areas and the green lane along the Etele road with this high percentage of canopy cover has resulted a very shady, dark and closed space feel.

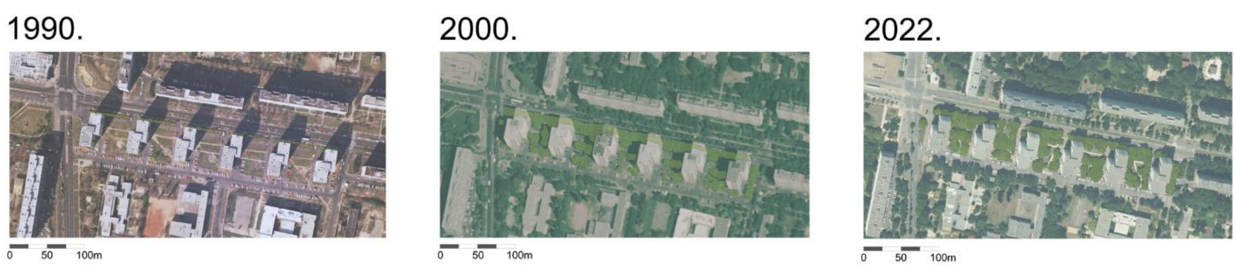

Figure 3. Canopy-cover study along Etele Road

Albertfalva liget saw similar processes in the past decades (Figure 4): in 1990, barely 10% of the park was covered by tree canopy, which grew to 28% by 2000 and 44% in 2022 (Figure 4). All three study areas demonstrate well that urban green areas can see a dramatic increase in and canopy cover in a relatively short period of time (Table 1.).

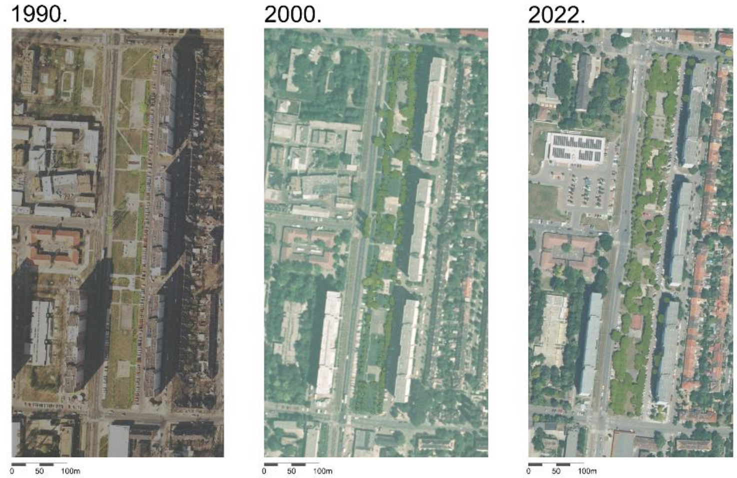

Figure 4. Canopy-cover study of Albertfalva liget

Table 1. Canopy cover study (comparison)

Name of the study area	Full size of the area (m²)	Canopy-cover (m²)			Percentage of canopy-cover (%)		
		1990.	2000.	2022.	1990.	2000.	2022.
1. Törőcsik Mari Park	50760	16967	20253	22276	33%	40%	44%
2. Etele-Tétényi road	12916	1378	6657	8158	11%	52%	63%
3. Albertfalva liget	48642	4853	13557	21439	10%	28%	44%

Tree density analysis of the three designated sub-areas (Table 2) shows that both Etele Road and Albertfalva liget saw an overall increase in the number of individual trees since 1990. Interestingly, the number of trees in the studied part of Törőcsik Mari Park (which already had well-established vegetation in 1990) significantly declined between 1990 and 2000 but has somewhat increased since. This shows that individual tree growth, while significant, is not the only factor contributing to the increase in canopy cover in urban green areas. As tree growth projections can only be applied to individual trees, this means that such formulas are unable to predict overall changes in large areas, as it is heavily influenced by the disappearance, and, more prominently, appearance of individual trees.

Table 2. The overall canopy study of the three different areas

Name of the study area	Detailed study sub-area (m²)	Number of tree specimen			Canopy cover (m²)			Percentage of canopy cover (%)			Growth factor at the tree stand level	Average crown diameter (m)		Growth factor at individual level
		1990.	2000.	2022.	1990.	2000.	2022.	1990.	2000.	2022.		1990	2022	
1. Törőcsik Mari Park	1446	22	16	19	489	726	789	34%	50%	55%	0,05	3,9	6,9	0,05
2. Etele - Tétényi road green areas	3044	12	27	25	219	1410	2254	7%	46%	74%	0,30	2,7	7,4	0,08
3. Albertfalva liget	1342	10	20	28	150	763	1001	11%	57%	75%	0,20	2,3	8,4	0,1

Based on our site surveys, we identified 4 distinct processes behind the increasing tree density on our study areas (Figure 5.).

(1) Organized (municipal) tree planting programs
(2) Trees planted by residents or local groups as individual initiatives
(3) Trees growing spontaneously from seed or other forms of propagation
(4) Individuals originally designed as shrubs - typically as hedges - growing into trees due to insufficient maintenance or erroneous choice of taxa in the design process

Figure 5. The 4 distinct processes behind the increasing tree density

All four processes contribute to the increasing tree density and canopy cover in different ways. Spontaneous seedlings and shrubs growing into trees mostly occur in areas with inadequate maintenance or already dense tree cover, creating a self-propelling loop of increasing density. It is also important to mention that this process in particular can increase already existing inequalities in green infrastructure within urban areas, with most new trees appearing in places with already established tree populations. Municipal tree planting programs can introduce a large number of new trees at once, transforming the image and spatial structure of green areas. Individual initiatives typically result in the planting of fewer trees, but with even less consideration about the spatial structure and plans – they can even cause conflicts if the newly planted tree is located in a spot where it cannot legally grow (e.g. because it would disrupt underground utility lines) or too close to another existing tree.

Newly appearing trees have an impact on the design and usability of green spaces as well. By reducing the amount of light reaching ground level, an increased canopy cover can lower temperatures in summer months, making green areas more suitable for human use during heat waves, while they also transform conditions for shrubs and herbaceous plants previously planted there. Newly planted trees, especially if they appear in large numbers, reduce the amount of open grassy areas suitable for picnics or ball games. Also, by creating new focus points, vertical elements and spatial walls, an increased canopy cover and/or tree density can reduce the visibility of existing elements (e.g. solitary trees), block visual connections and close down originally open spaces.

Discussion and Conclusion

Our results highlight that in urban green spaces, canopy cover and tree density can rapidly increase if conditions are suitable. Municipal tree planting programs are one of the most prominent factors behind this process, which often introduce a large number of new trees to areas that already have an acceptable canopy cover. In fact, such planting programs can actually be counterproductive, by blocking visual connections and reducing usability while only adding a small amount of green surface to their surroundings. Increasing density can also become a self-propelling process, with seedlings appearing among densely clustered trees. Furthermore, maintenance resources spread between an increasing number of trees, spontaneous seedlings and trees planted by residents in unsuitable locations are more likely to go unnoticed, while plants originally intended to be maintained as hedges or shrubs can grow into even more trees. While municipalities often see parks and green areas as great (and especially non-problematic) places to plant even more trees in programs focused on quantity over quality, further accelerating the process of increasing tree density. A paradigm shift is necessary in urban tree planting initiatives – instead of the number of trees planted, they should focus on reducing green infrastructure inequalities within cities.

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