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A KLÍMAVÁLTOZÁS HATÁSAI A TÖRTÉNETI KERTEK ÉLŐ ÖRÖKSÉGÉRE

Történeti faállományok fenntartási és megújítási lehetőségei

THE EFFECTS OF CLIMATE CHANGE ON THE LIVING HERITAGE OF HISTORIC GARDENS

Maintenance and restoration opportunities of the historical tree plantings

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ABSZTRAKT

Az éghajlatváltozás hatással van környezetünk alakítására és súlyos fenntarthatósági, esztétikai problémát jelenthet minden régióban. A történeti kertek növényállományában, különösen a fák esetén aggasztó károsodások figyelhetők meg, melyeket a heves viharok, a csapadék és a talajvíz csökkenése, a kritikus hőségperiódusok, valamint az új kártevők és növénybetegségek megjelenése okoz. A történelmi kertek, örökségi és tájképi helyszínek magas kulturális, társadalmi és környezeti értékeket képviselnek. Az évszázados élő örökség, a legértékesebb ökoszisztéma elem, időről időre rendszeres fenntartást és részleges vagy teljes helyreállítást igényel a hagyományos felújítási programok keretében. A megőrzésnek és a szakszerű fenntartásnak figyelembe kell vennie a regionális és helyi sajátosságokat, a megváltozott klimatikus adottságokat is. Bár Magyarország viszonylag kis területű ország, a helyi és kistérségi klímatípusok változatosak, ezért két történelmi kertet (Nagycenk, Széphalom) választottunk esettanulmányi helyszínnek. Az egyik a nyugati, a másik a keleti régióban található, két különböző éghajlati adottságot reprezentálva. A kutatás az idős faállomány körében kihívást jelentő állapotokat tárt fel. A levont tanulságok hasznosak lehetnek a kertrekonstrukciós programok során a telepítések tervezésében, valószínűleg nem csak Magyarországon, hanem nagyobb európai léptékben is.

Kulcsszavak: éghajlatváltozás, történeti kert, veszélyeztetett fa taxonok, növényalkalmazás ⦿

ABSTRACT

The growing impact of climate change on planting design and garden maintenance became an often debated, severe environmental and aesthetic problem in all regions. The worrying damages of heritage sites' plantations, especially the trees, are due to local climate change symptoms, heavy storms, decreased precipitation and underground water, critical heat periods, and the invasion of new pests and plant diseases. Historic gardens, heritage sites and landscapes represent high cultural, social, and environmental values. The centuries-old living heritage needs regular maintenance and partial or overall restoration from time to time within the frame of traditional renewal programs. Conservation and specialised maintenance should consider the regional and local characteristics. Though Hungary is a relatively small Central-European country, local and small-scale regional climate types are diverse. Therefore, we have chosen two historic gardens (Nagycenk, Széphalom) as case study sites, one in the western and the other in the eastern region, representing two different climate conditions. Based on the tree stock survey, the research discovered challenging conditions among the most valuable ecosystem elements, the mature tree stock. The lessons learnt could be helpful in planting design during garden restoration programs, probably not only in Hungary but also at a larger European scale.

Keywords: climate change, historic garden, endangered tree taxa, planting design

1. INTRODUCTION AND RESEARCH QUESTIONS

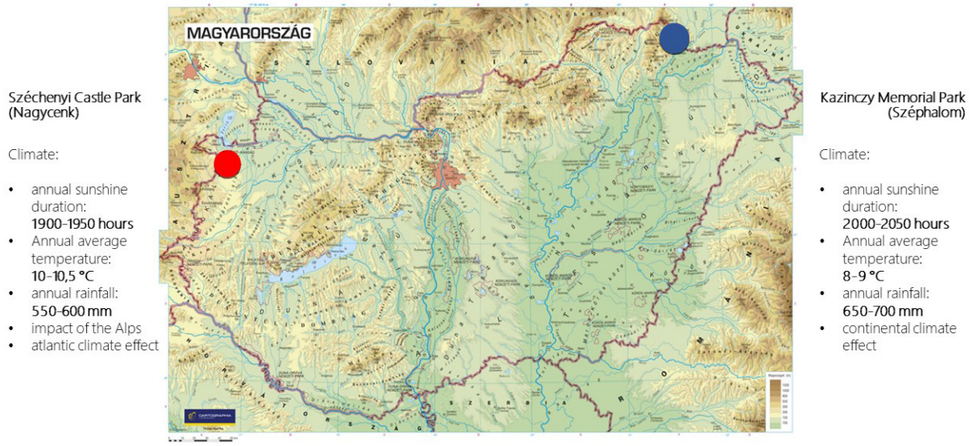
A historic garden, like any garden, is an open space that symbolises Eden [1]; it represents historical values, enchanted and remote microcosm, supra-individual organisation, as a community (biocoenosis), depending on location, space, size, and style. Based on Florence Charter classification [2], historic gardens are architectural and horticultural compositions and "living monuments" with a particular public interest from a cultural point of view, independently from the historical style, design, surface, and property. Moreover, they are essential green elements in terms of ecosystem services, recreation, tourism, and culture. Therefore, the appreciation, preservation, and reconstruction of historic gardens and parks represent a vital issue in Europe and even urgent tasks in Hungary [3].

1.1. The impact of climate change on the vegetation of gardens and living heritage

Climate change and its impact on the environment is a widely researched topic. Bisgrove and Hadley (2002) summarise three interrelated phenomena according to the potential climate change impacts on gardens. First, the climate change itself in a global and regional context that modifies the basic climate elements such as temperature, precipitation and wind; second, the extreme weather events such as super thunderstorms, torrential rains, floods and long-term droughts, with the ongoing consequences on the soil and water system; third, territorial loss and damage caused by infrastructure development and urbanisation [4]. Local environmental changes may often exacerbate global climate change. Climate change is predicted to affect Hungary significantly. Global and regional models expect an annual and seasonal temperature increase in significant agreement, while precipitation changes are highly uncertain in yearly sum and monthly distribution [5, 6, 7].

According to the model ensemble of the FORESEE database [8], the Central European precipitation sum might decrease by 3% up to the end of the 21st century. The frequency of extreme drought events in Hungary is predicted to increase, mainly in summer and spring, according to an ensemble of 11 models [7]. The RegCM and Aladin regional climate models indicated that the annual mean temperature of Hungary might increase by 3–5°C to the century's second half [9], and most of the country will suffer from precipitation decrease in the near future [5, 9]. In addition, there are other consequences of environmental change; for example, extension of the vegetation period, earlier generative stage (more flower and crop production), overlapping or shortened flowering period,

Figure 1: Geomorphology and the climatic conditions of the case study sites
Figure 2: Historical background of the Széchenyi Baroque gardens



second flowering periods, etc. Studies between 1961-90 show that cold-tolerant plants have significant advance (8 days) in their vegetation period, but warm-demanding plants' advance is less significant (2 days). At 2 degrees of warming, the general vegetation time might lengthen by eight days in average [10]. Other effects are: increase in daytime and dawn temperatures (photosynthesis); phloem impairment (above 45°C heath, the plants' water transport decreases, trunk cooling decreases, plant mortality risk increases); trunk and foliage damage (necrosis); changes in winds, increase of stormy winds, effects on tree crown and branches. One of the worst challenges to plant health is the increasing spread of pests and diseases caused by the warming climate and milder winters [11].

Drought might not occur uniformly, but significant regional differences could be typical in the future. Research by Bede-Fazekas & Szabó (2019) also shows that the northwest and northeast regions in Hungary were the least arid (optimal) areas in the reference period (1961-1990). In the projected periods, the north-western region may experience significant drying compared to the reference period, while the north-eastern areas may remain close to the reference level in the two projected periods (2021-2050 and 2071-2100) [12], and this is supported by the recently published drought map (National Meteorological Service). The projected drying would result in a significant maintenance surplus in the more arid areas, which, even if secured, could pose a high risk to the survival of the present tree populations.

Primary plants, especially trees, are increasingly sensitive to climate and environmental changes as main living heritage elements. The indirect effects, like decrease of the subsoil water level, increased evaporation, extended drought periods, the collapse of traditional soil ecosystems etc., might spill over and cause further environmental, economic and social, or human health problems. Providing favourable living conditions and sustaining the valuable ecosystem may support the heritage sites. The original composition, the aesthetic, ecological, historical, and cultural values, and character could be preserved at least on a large scale. Adapting to changing climate might require a new planting design concept introducing various new species, cultivars, and even cultivation methods. At the same time, plants for humid and wet habitats could be selected out of the recommended plants' list [13, 14, 15, 16, 17].

1.2. The consequences of functional changes on the vegetation of historic gardens

All gardens, including today's historic gardens, came to birth for specific functions and use depending on the ownership, the cultural and economic background. Beyond representation and the demonstration of political and economic power, the garden offered the experience of recreation in nature. Ownership might change from time to time, as well as the social context; the once self-sustaining economic entity often fall into pieces with a loss of territorial integrity. The lack of regular maintenance led to a severe decline in many historic gardens.

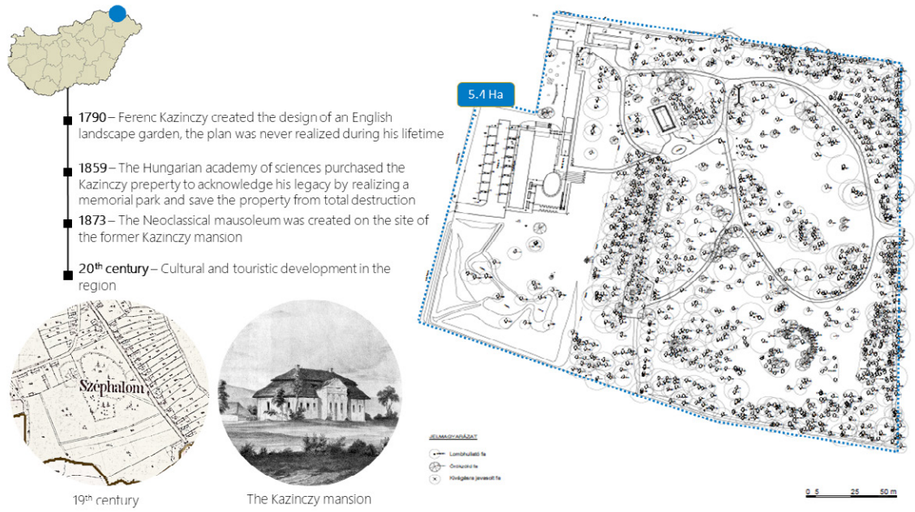
In the second half of the 20th century, the growing interest in landscapes, natural monuments and sites brought gardens and parks to the forefront of heritage protection. Meanwhile, tourism has also undergone significant changes, making it more competitive and imperative, with tourists looking for unique and unforgettable experiences [18]. Historic gardens and parks, which provide unique impressions, visual experiences, cultural imprints, and closeness to nature and art, fit well into this context. The garden itself has become a tourist attraction. The emergence of mass tourism needed several new infrastructure facilities and services, such as parking lots, service buildings, restaurants, cafés and terraces, shops, children's areas, public sports equipment etc. In addition to individual garden visitors, guided walks, and occasional events (weddings, concerts, festivals) cause additional threats, especially for the garden vegetation. Furthermore, visitors trampling may cause soil compaction and structural and drainage problems [19].

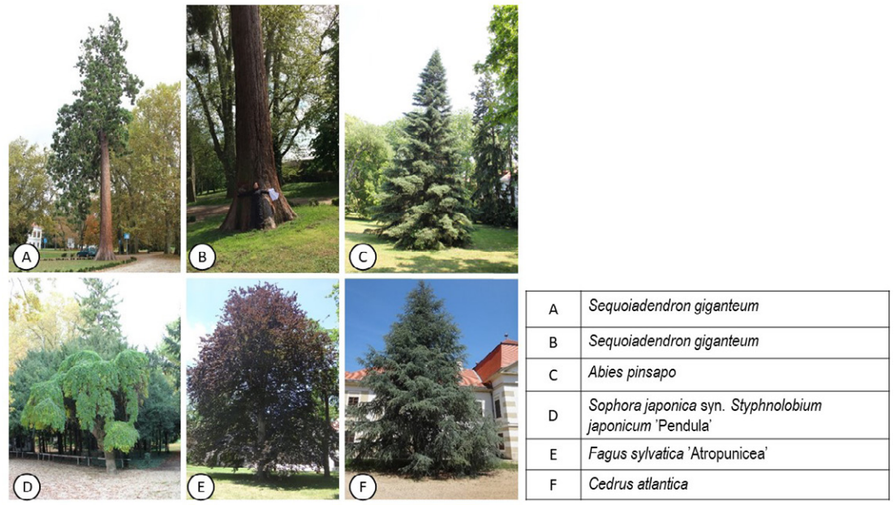
Climate change may also affect garden use. Milder winters, longer summers, the extension of the vegetation season and the period favourable for staying outdoors expand the opportunity for active garden uses. [20]. In addition, the pandemic, the associated lockdowns, and the restriction of social life indoors have also increased the demand for open green spaces.

In conclusion, more visitors are expected to green areas, including historic gardens offering high-quality recreation. Furthermore, in connection with consumer needs, the range of services available in the gardens help to enhance attractiveness [21]. However, higher visitor numbers and the service infrastructure may increase the functional impacts on gardens and the landscape ecosystem. At the same time, garden maintenance and restoration costs require a regular income; if not the estate's once well-balanced economic system, then the recreation business, the visitor fees and programme revenues may help to balance the budget. However, the unfavourable effects of increased use might require more intensive professional maintenance [22].

This paper aims to evaluate the woody plant communities in two historic gardens in two different regions, the Széchenyi Castle Park in Nagycenk and the Kazinczy Memorial Park in Széphalom. Research surveys were conducted in 2017 and 2018 at these sites. The aim of the tree heritage surveys ordered was to support the conservation of the living heritage and the planning process of the reconstruction. We examined what maintenance is required in the present climatic conditions and environmental changes to secure the gardens' sustainability, protecting especially the mature tree canopy. We collected the main research questions based on the detailed tree stock survey. Which tree taxa may be at high risk due to climate and habitat changes? Is it still possible to stick to an authentic planting scheme when reconstructing

Figure 3: Historical backround of the Kazinczy Memorial Park
Figure 4: Picturesque conifers and deciduous trees at Nagycenk, Széchenyi Castle Park





A	*Sequoiadendron giganteum*
B	*Sequoiadendron giganteum*
C	*Abies pinsapo*
D	*Sophora japonica* syn. *Styphnolobium japonicum* 'Pendula'
E	*Fagus sylvatica* 'Atropunicea'
F	*Cedrus atlantica*

historic gardens? Is it still possible to keep characteristic or emblematic taxa in historic gardens? Is it possible to invest in high-quality maintenance of individual trees and habitat restoration? To what extent should reconstruction requirements and garden maintenance methods be modified? Are there regional trends in habitat and vegetation change in historic gardens?

2. MATERIAL AND METHOD

Historical maps, military surveys and cadastral maps offer well-detailed information on how landscape pattern and land uses changed in Hungary in the past two or three centuries due to the social and economic development, changing cultural life and political system. The highly disproportionate spatial distribution in the 18th-19th century results from the geographical position and the landscape assets shaping the Hungarian Kingdom's development after the defeat of the Ottoman Empire in the Central-European region.

2.1. The landscapes of the survey sites; geomorphology and climate

The Habsburg Empire's political centres, Vienna and Bratislava (Pozsony in Hungarian), where the national assembly of feudal Hungary held its sessions, promoted a dynamic growth in the western Hungarian regions. From the 18th century, the high aristocracy's Baroque estates organised the landscape with the establishment of castles, estate gardens, parks and hunting forests, views, and allées. As a result of expanding cropland farming, besides hunting, extensive field cultivation and pastures increased agricultural production and restructured the landscape. For several periods in its history, the vast wetland of Hanság was planned to be dried out and turned into arable land. Finally, the centuries-long drainage concept was successfully finished in the mid-20th century but resulted in a considerable loss and persistent shortage in the regional water system [23]. The profound change in the water system, the land cover and the land use pattern played a triggering role in the local and regional climate change. The first case study site, Nagycenk, adjacent to the Fertő-Hanság region is impacted by these processes.

The other historic garden, the Kazinczy Estate at Széphalom (now under the administration of Sátoraljaújhely), lays in North-East Hungary at the foot of Zemplén Hills, near to the Tokaj Wine Region. The Zemplén Landscape Protection Area offers an inviting diversity in landscape character and natural values. From an economic aspect, this region is still moderately developed. Széphalom, the former Kazinczy Estate, a memorial site, and the Museum of Hungarian Language serve as a place of national cultural pilgrimage. The traditional land uses, agriculture, forestry and viticulture, are still characteristic. At the same time, the religious and cultural urban centres, along with the industrial development of the 20th century, offer multifunctional urban fabric and residential services.

According to long term regional climate models, the climatic conditions of the two regions will change in the distant future [5, 7, 9]. Nowadays, the western part of the country experiences worse rainfall conditions. However, long term models by 2100 predict that the conditions will change, with a more significant reduction in rainfall in the vegetation season in the western areas; as a result, the vegetation of historic gardens may need intensive watering and high level of maintenance to protect the living historical heritage. [13].

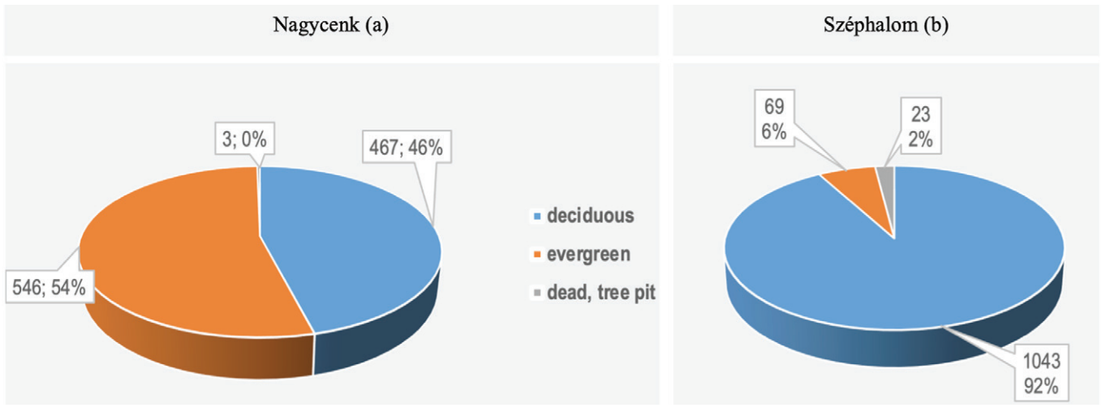
2.2. Historical background of the survey sites

In Hungarian history, Nagycenk is linked with the Széchenyi family from the early 18th century, when Count Antal Széchenyi began expanding and developing the mansion and creating the first garden in Baroque style. Ferenc Széchenyi (1754-1820) moved to Nagycenk in the early 1780s, creating one of the first English landscape gardens in Hungary. First, he renewed the estate with creating a new garden along the small creek on the south, and later converted the Baroque front garden into a landscape garden [24]. Ferenc Széchenyi's garden construction was continued by his son, István Széchenyi (1791-1860) and was completed as a classic English landscape garden in the 1820s. In addition to territorial expansion and garden beautification, he dealt with the versatile estate development, enriching the landscape by planting mulberry trees in order to develop domestic silk production. The garden design and plant diversity of today's collector's garden image praises Béla Széchenyi's (1837-1918) work. The Széchenyi Estate holds a significant cultural value owing to the contribution of the Széchenyi family to the cultural and economic development of the country. It is a memorial museum and a significant touristic and cultural attraction [25]. The castle and garden reconstruction started in 2021.

The other survey site, Széphalom, lies somewhat north of Sátoraljaújhely, the regional economic centre. The name Széphalom (a small, pleasant hill in Hungarian) was given after the natural landscape that once existed here in the late 18th century by Ferenc Kazinczy (1759-1831), an enlightened scientist and philosopher, a fiscal, poet, writer, linguist, founding member of the Hungarian Society of Scientists (later Hungarian Academy of Sciences), and a self-made master of garden art. Kazinczy is closely connected to Hungarian garden art and the first period of the English landscape garden movement [26]. His writings about the Hungarian and neighbouring regions' gardens reflect a deep and versatile theoretical garden art knowledge [27]. At the turn of the 18-19th century, Kazinczy built the Széphalom House by evoking the natural landscape. Unfortunately, the English garden for Kazinczy remained a plan due to his personal problems and family issues, and a shortage of financial coverage. The Hungarian Academy of Sciences created the Museum of Széphalom, the nowadays protected nature conservation area and historic garden in

Figure 5: Some tree health symptoms inthe Kazinczy Memorial Park at Széphalom
Figure 6: Ratio of deciduous trees and evergreens in Nagycenk (a) and Széphalom (b)

A	Exposed roots in the hornbeam (*Carpinus betulus*) trees
B	Bacterial discharge on the trunk of a pine tree
C	Asymmetrical, weak and truncated crown at the Scotch pine (Pinus sylvestris)



the mid-19th century, to express the nation's gratitude and respect. The Kazinczy garden's reminiscences smoothly fit into the classical landscape style garden.

2.3. Survey and assessment methods

The measurement and evaluation of the tree stock of in the gardens was based on the method and criteria of the Hungarian Association for Tree Management (MFE) [28, 29]. The dendrological survey contains overall tree records, where the dendrometrical characteristics include the full tree height, trunk height, trunk circumference size, trunk diameter, and crown diameter in numbers. Trunk diameters come in two ways: as measured average diameters or calculated from the trunk circumference. All trees are unique and form a physiologically coherent whole. A detailed examination is necessary because the quality of the habitat is often different from the ideal, which affects the life chances of the tree. During the visual inspection, the general state of the roots, trunk, and crown are essential. We applied the EU conform method developed by MFE, which uses five parts and values:

A – root system, including roots and collars and the type and condition of the plantation site.
B – trunk condition.
C – crown condition, including the crown base and the full crown (branches, branchlets, twigs, and shoots with leaves).
D – assessment of viability.
E – degree of care, maintenance.

Besides the detailed tree stock measurement, the survey method also considers the overall health condition, the maintenance level, the quality of the tree biotope, particularly the mature trees and the assumed sustainability. Furthermore, the aspects related to the plant community cover the survey of tree canopy density and the issues of weed plants. The assessment covers six main survey criteria:

1. presence of ageing specimens,
2. planting density,
3. taxon diversity,
4. weed trees and invasive species,
5. sustainability initiatives in gardens,
6. level and quality of maintenance.

3. RESULTS

3.1. The assessment and evaluation of the trees in the gardens

The tree survey at Nagycenk, in the Széchenyi Castle Park, was carried out in 2017 and included the assessment of 1016 individual trees. The garden reconstruction plan in the frame of the National Castle Programme could reasonably rely on the survey. Hence, the protection of the living heritage played a vital role in the planning process. Though the famous Baroque linden tree allée is part of the 18th-century garden concept, here we focus only on the castle garden [25, 30, 31]. The garden has changed from late Baroque to early, then to the classical English garden during its long history.

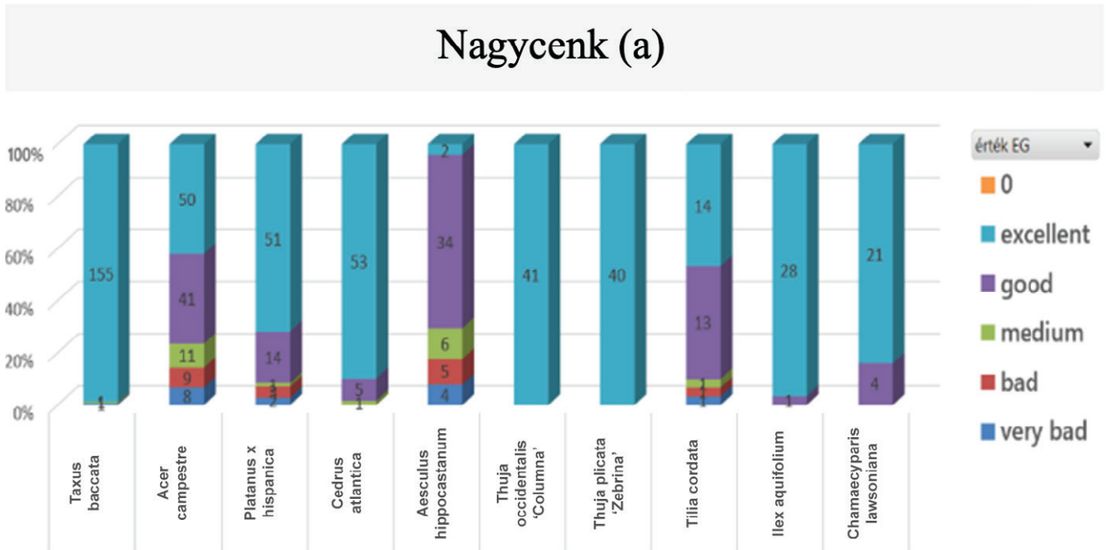
At the same time, in the second part of the 19th century, it gained a collector's garden character which is still well reflected in the present tree canopy. The reconstruction started in 2020, together with the restoration works of the castle's-built heritage by the National Heritage Protection and Development Ltd.

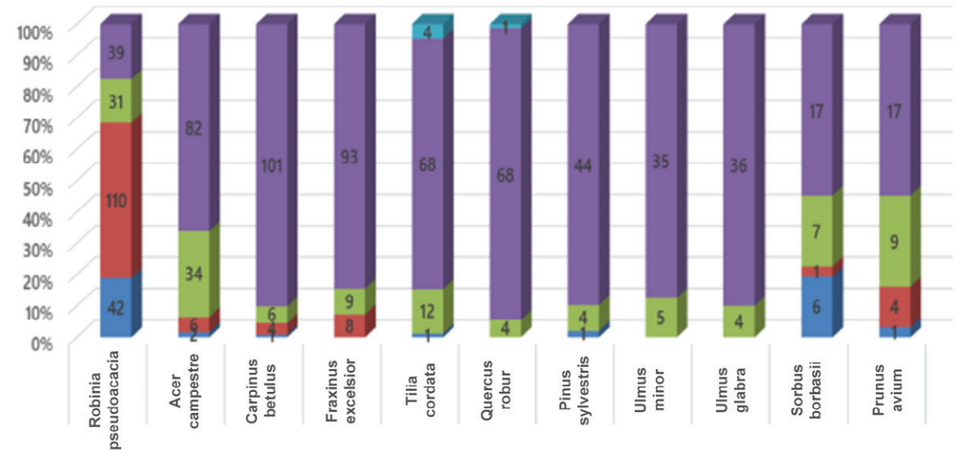
The proportion of evergreen and deciduous tree specimens is clearly shifting towards evergreen. There are more evergreen species (546 individuals, 53,7%, 55 taxa) than deciduous ones (467 individuals, 46%, 72 taxa). By 2017, three trees had died (Fig. 4). Dominant species are plane trees (*Platanus* sp.) and yews (*Taxus* spp.) Some dominant, huge trees characterise the garden space: the giant sequoia with 188cm trunk diameter *(Sequoiadendron giganteum)* (Fig. 5a-b.), a Caucasian wingnut *(Pterocarya fraxinifolia)* with 239cm trunk diameter, and seven London plane trees *(Platanus × hispanica)* with over a 150cm trunk diameter. A total of 84 trees have at least 100cm trunk diameter (8,3% of the whole tree stock). At Nagycenk, we experienced a high value in taxa diversity and several excellent specimens (Fig. 5); owing to the soil, species that require neutral and acidic soils (several *Rhododendrons*) can also develop as optimal. The health values (Fig. 6) are primarily excellent (71%).

Many old, mature trees have fallen or died in the years following the survey due to the drying climate and unfavourable weather, as heavy thunderstorms and stormy wind. In addition, many old or mature trees suffer from the proliferation of old and new pathogens and pests due to difficult conditions. These symptoms can be seen on the enormous European ash *(Fraxinus excelsior),* the London plane (*Platanus × hispanica;* 404, 368, 315, 390cm trunk circumference), and mature horse chestnut trees *(Aesculus hippocastanum).* Among the evergreens, this subheading also includes tip-drying European spruce *(Picea abies)* and drying white fir *(Abies concolor).* Plants with weak habitat cannot concentrate on self-healing processes; hence, wounds caused by storms or pathogens often degrade to larger cavities, seriously undermining the trees' static safety.

In the classic landscape garden of Kazinczy Memorial Garden at Széphalom in the eastern region, we listed 1135 tree individuals during the 2018 survey. The traditional landscape garden elements like the conifer roundel (of *Pinus* specimens) and several allées (*Carpinus betulus, Tilia* spp., *Quercus* spp.) characterise the overall garden layout. The deciduous individuals are the dominant trees in the plantation (1043 deciduous and 69 evergreens that is 92 to 8% proportion) (Fig. 4). Dominant species are, first of all, the black locust *(Robinia pseudoacacia),* then the common hornbeam *(Carpinus betulus),* field maple *(Acer campestre),* and common ash *(Fraxinus excelsior)* represented by more than 100 species of each. The most characteristic giant trees are several oak trees *(Quercus petraea, Q. robur, Q. rubra),* common horse chestnut *(Aesculus hippocastanum),* lindens *(Tilia cordata, platyphyllos),* and checker tree *(Sorbus torminalis).* Only 1.2% of the tree stock has an over 100cm trunk diameter (9 *Quercus robur,*

Figure 7: Health values of the 10 most common species in the examined gardens, Nagycenk (a), Széphalom (b)





2 *Tilia cordata*, 1 *T. platyphyllos*, 1 *Robinia pseudoacacia*, 1 *Fraxinus excelsior*). The observed character is deficient in the shrub level, but there are valuable herbaceous spots (*Anacamptis morio, Stellaria holostea,* etc.). The health values are mostly good (65%); there are fewer excellent trees, only eight specimens (Fig. 5, 6.).

The health values of the ten most common species in the examined gardens, Nagycenk (a) and Széphalom (b) (Fig. 7a-c.), show that the Nagycenk garden trees represent a more favourable condition due to the better soil and probably a higher quality in maintenance.

Based on some comparative assessments (Fig. 9), the proportion of young trees (trunk diameter up to 30 cm) is 23% at Nagycenk (19% and 4%) and 60% at Széphalom (41% and 19%). The next trunk category (diameter between 31-90 cm) is 33% at Nagycenk and 36% at Széphalom. The distribution for older trees with diameters between 91-120 cm is 5% and 1%, respectively. Finally, the distribution for the mature old trees (trunk diameter greater than 120cm) is 5% and 3%, all this because the survey of the Nagycenk garden included larger shrubs for which no trunk diameter measurement was made, and this figure is relatively high in this garden (34%). Thus, the estimated age distribution suggests that Nagycenk has a much higher number of wise trees, around 200-220 years old, while the age distribution in the Széphalom garden is about 150 years. The estimation is based on a visual survey and the gardens' historical periods and evolution, as no dendrochronological studies have been carried out.

The incidence of weed trees is extremely different in the gardens due to different garden maintenance intensity, vegetation weed infection of neighbouring habitats, and the original planting design ideas. Fortunately, the Nagycenk garden has only one invasive individual tree. On the other hand, the Széphalom garden has 650 invasive trees.

The graphs below show the health values of the ten most common species in the given gardens.

3.2 Conflicts and main issues of the living heritage of trees

We could identify the main existing conflicts and problems resulting from the systematic analyses performed at the two case study sites. Furthermore, the historical evolution (summarised in 2.2) and the detailed dendrofloristic survey, the overall condition, and the dendrological values offered a precise categorisation of the assessment criteria; hence, six different conflict issues can be identified for the sites.

The **first** issue is the number and proportion of ageing individuals, which strongly correlates with the gardens' history. For example, Széphalom has just a few large trees (1,2%), while at Nagycenk, a much higher number of large trees could be identified (8,3%). These mature trees add significant value to the garden's atmosphere and character; on the other hand, they are more vulnerable and sensitive to all sorts of habitat changes.

The original trees in the historic gardens can be hundreds of years old, depending on their history and evolution. These plants are mature and may have several physiological difficulties in their ageing periods. In addition, the lack of maintenance, the deteriorating conditions, and the impact of climate change – especially the lack of water, decrease of underground water level, and the growing threat of stormy wind periods – exacerbate their health and stability problems. As a result, old trees may increase the safety risk for garden users.

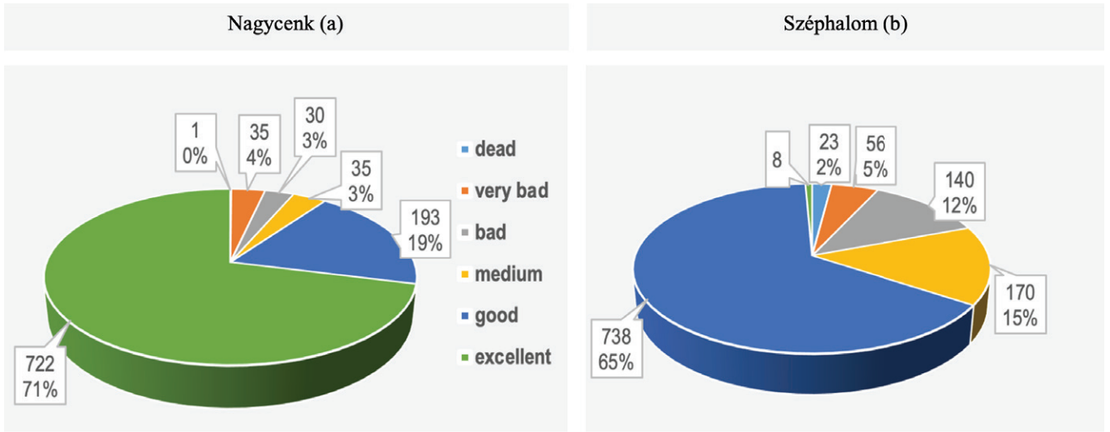
We found 84 trees in the Nagycenk garden with a trunk diameter of over 91cm. These trees might be called the wise trees; they are the non-native *Liriodendron tulipifera, Platanus spp., Sophora japonica, Aesculus hippocastanum, Pterocarya fraxinifolia, Ginkgo biloba,* the evergreen *Sequoiadendron giganteum* and *Thuja orientalis,* and the native *Acer campestre, Quercus robur, Fraxinus excelsior, Tilia cordata, Fagus sylvatica.* On the other hand, in the Kazinczy Garden in Széphalom, there are only 12 mature trees (only one non-native invasive species such as *Robinia pseudoacacia* and three indigenous *Tilia cordata, Tilia platyphyllos, Quercus robur*).

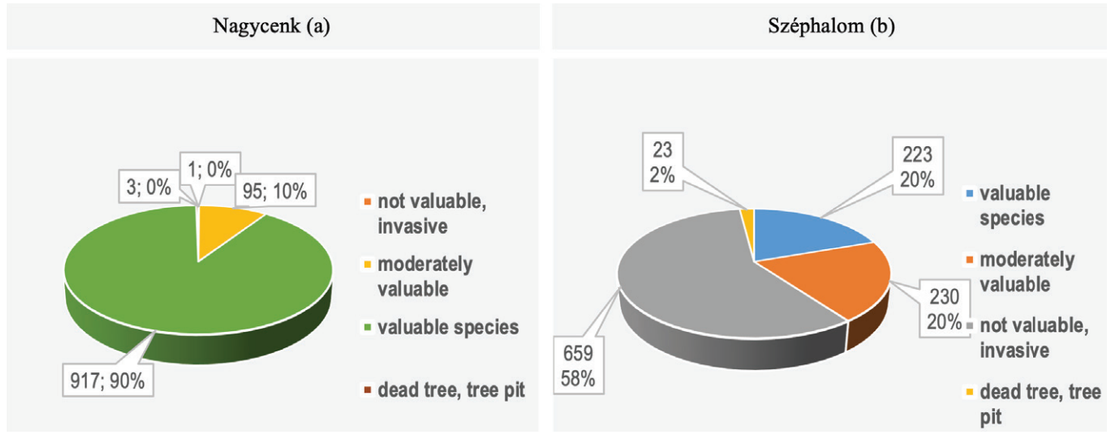
The **second** conflict is related to the density of plantations. At Széphalom, the tree plantation is characteristically dense in the wooded areas. At Nagycenk, the density is close to optimal as the trees can develop the typical crown for the species; the crowns are not forced to climb high in search of sunshine. From a statical point of view, the trunk–crown proportions are good; no trees with small crowns and tall trunks are formed. The dense stands at Széphalom are partly due to the spread of black locust *(Robinia pseudoacacia)* rootstocks, resulting in a monotonous character of several garden sections. Unfortunately, some valuable design elements, such as the rondo and the main allée, significantly degrade. The *Carpinus* tree allée leading to the small Kazinczy cemetery is completely stunted at the bottom due to the dense planting. The trees have run-up in a struggle for light, and they neither function as a hedge nor as individual trees. Even the highly compacted soil is an unfavourable habitat condition (many roots are exposed due to the lack of air). Still, the narrow linear space formed by the densely planted trees creates a unique spatial character and an atmosphere excellent for the arrival to the small cemetery.

Taxa diversity is the **third** issue. Nagycenk has a rich profile with 127 taxa, while Széphalom presents a weak diversity with 48 taxa. The Széphalom garden is very poor in water-demanding taxa, represented only by red oak *(Quercus rubra).* The diversity at Nagycenk is due to the larger number of taxa and the different shapes and habits, the colourful foliage of the varieties. Examples include weeping taxa such as *Sophora japonica* 'Pendula', *Chamaecyparis nootkatensis* 'Pendula' or purplish foliage trees such as *Fagus sylvatica* 'Atropunicea', many variegated cultivars, and unique species such as *Torreya taxifolia,* which is very rare in Hungarian gardens.

The **fourth** identified problem is the number of weed plants. In Nagycenk, only one weed tree was detected, an *Acer negundo.* In contrast to that, at Széphalom, 232 *Robinia pseudoacacia* individuals live, representing

Figure 8: Some tree health symptoms in the Kazinczy Memorial Park
Figure 9: Dendrological values in Nagycenk (a) and in Széphalom (b)





more than 20% of the tree population in the garden. Such a significant population poses a great danger for the plantation since it can easily and rapidly spread, disturbing the garden character and surpressing other species. The high presence of invasive individuals makes it very difficult to maintain quality both short and long term. At the same time, climate change continues to favour the occupation and spread of invasive and weed taxa. In addition, the large amount of *Robinia* consists of many densely grown, less valuable specimens with zigzag trunks unhealthy and imperfect crowns, which impoverish both shrubs and grasslands and reduce biodiversity. In order to replace them continuously and periodically in the future, it is worth planting valuable climate-tolerant species that do not tend to invade. The restoration of gardens must consider the historical landscape and nature's capacity for regeneration. This can also lead to the introduction of invasive species or plants with low dendrological value, the removal of which is an essential maintenance task [32].

When analysing and understanding contemporary issues of historic living heritage, it is crucial to consider sustainability innovations such as stormwater management, the **fifth** issue. In Nagycenk, unfortunately there are no such innovations. However, the presence of a rain garden shows the contemporary garden design approach at Széphalom, bringing sustainable solutions to its garden without disrupting the historical parts of the site. Furthermore, in the early 2000s, in the framework of a thematic development of Széphalom, a new building for the Museum of Hungarian Language appeared on the border of the historic garden. The museum's garden serves the necessary open space functions for the institution and creates a smooth and sustainable transition to the Kazinczy memorial garden.

Lastly, the **sixth** analytical issue is the maintenance level, one of the essential aspects of a garden's thriving. Unfortunately, both sites have low maintenance levels, mainly due to the insufficient number of gardeners and a lack of funds. The lack of timely grass pruning, tree surgery, the old and mature trees with many dry branches, trunk issues cry for intensive and professional garden maintenance (Fig. 8). However, since our tree stand surveys, the reconstruction of the two historic gardens has started (Nagycenk) or was finished (Széphalom).

The preservation of less climate-tolerant or disease-sensitive but characteristic or emblematic taxa in the intensively maintained sections of historic gardens seems more possible than historical remembrance. In all other cases, it is worth thinking about a substitute taxon, which allows the garden's flora to be valuable at the moment of handover and provide its positive abilities and ecosystem services for many decades.

It is worthwhile to invest energy in quality individual tree maintenance and habitat restoration and prepare a long-term maintenance plan to be performed, which includes in detail the tasks of tree care, plant protection, and all other matters concerning the garden. Unfortunately, canopy-level treatments do not necessarily provide adequate care and maintenance in the long run.

4. DISCUSSION

When dealing with the preservation of cultural landscapes such as historic gardens, it is essential to consider the contemporary challenges and possible sustainable approaches. Nonetheless, creating a sustainable model must always respect the garden's authenticity and original features, in addition to allowing space for contemporary and innovative interventions [33].

According to Š´citaroci et al. (2019), "Gardens are not nature, although they may look natural at first glance. They are not natural as they result from man's work, interpretation, design and maintenance. Nature maintains itself, while man must tend gardens because they cannot survive without him". This statement can be considered a simple and accurate description of a garden, leading to the interpretation that it is a living organism in constant change, thus the need to implement sustainability approaches to contemporary interventions.

There are many factors for ecological sustainability considerations, as studies of historic Persian gardens have shown. These include supporting living processes, not damaging the existing site, and resilience to contemporary changes as another essential characteristic of success [34].

We can first highlight the importance of climate-adaptive plant application by applying the sustainability concepts to this research, and the two gardens studied. In this ever-changing environment and climate crisis, it is crucial to choose resilient species that can survive and thrive in this challenging contemporary environment, where pollution, new pests/diseases and higher temperatures are vital factors. For example, due to the predicted climate change and regional ecosystem changes, a severe decrease in precipitation and soil-water system, and as a consequence, extended drought periods and dangerous attacks of new species of pathogens and pests typical in a warming-up situation might come in the future. Therefore, the dominant solitary specimens at Nagycenk, such as the giant sequoia *(Sequoiadendron giganteum)* and the large stocks of sycamore *(Platanus × hispanica),* are more challenging to maintain in the future decades. The possible loss of these mature trees would cause severe deterioration in the garden's spatial composition, focuses and character; moreover, these trees, witnesses of a bygone time and the cultural and garden art history, belong to the vital set of living historical heritage.

According to several authors [35, 36, 37, 38], the historic garden is a cultural heritage site for plant species collection; therefore, conservation of species diversity is necessary. In the case of the Nagycenk garden, the species variety seems to be a valuable element of the heritage. The variety of taxa planted in the garden may help to mitigate climate change effects. Thus, in the future, special attention should be paid to the species richness of heritage gardens to promote faunistic diversity and

test planted species' acclimatisation and compositional benefits. The replacement of water-demanding taxa with so-called climate trees (climate-adaptive species), which have already demonstrated drought tolerance, is justified in place of the coppice species [39]. One example is the use of *Acer monspessulanum* and *Acer truncatum* and hybrids instead of the currently occurring Acer negundo and Acer saccharinum species (in Nagycenk), which are not only invasive or potentially invasive species but also prefer wetland environments. The dominant stand of London plane trees in the Nagycenk garden consists of very vigorous mature specimens. Still, the current *Platanus × hispanica* specimens will be replaced mainly by *Platanus orientalis* species and varieties, which have better drought tolerance and disease resistance. In the case of linden species, the most drought-affected native species is the large-leaved linden *(Tilia platyphyllos).* Still, even the small-leaved linden *(Tilia cordata)* shows wilting symptoms or leaf drying during the summer drought [40, 41]. Mongolian linden *(Tilia mongolica)* might be preferred in their place as it proved well even in extensive areas. All these proposals are only examples of the replacement of species of specific genera. Still, the evaluation of possible future environmental conditions requires further research, which is now based mainly on the study of the plant population of extensively maintained collector's gardens.

As for the planting design, it is essential to develop proper plans for species change or tree replacement if needed. Moreover, a detailed custom-made list is necessary for each historic heritage site defining the species to be banned/avoided for the reconstruction [41]. Besides restrictions, a proposal of applicable species should help the renewal process. From a planning perspective, there should not be only an individual action, but preferably shared experiences and principles learned from smaller regions' case studies

Another important aspect is the economic situation of historic gardens. Achieving sustainability in historic gardens can be challenging since they were never financially sustainable, hence the enormous costs of maintenance [33]. For such sites to be more sustainable, there should be more financial support for castle gardens, arboreta, etc., to maintain an ideal quality of the sites. Furthermore, with more financial means, there would be more room for necessary training of professional gardeners, specifically in maintenance of historic gardens. Moreover, surveying the plant use in historic gardens and developing an organised and rich database can help to make the sites more sustainable.

5. CONCLUSION

Old trees in historic gardens have many values and provide complex ecosystem services: their social, economic, urban, cultural, architectural, biological and ecological benefits and services are generally known to all. Still, as shown in the article, they are endangered, thus it is necessary to raise the awareness of decision-makers and the public in this field. This will further increase the appreciation of old trees, especially in historic gardens. Planning, development, and maintenance in reconstruction of historic gardens must focus on the old and mature trees' best interests. The original planting concept is a priority, and the replacement of mature trees should follow a detailed long-term plan, with each garden being assessed and evaluated [42]. A well-considered choice of tree species can also help adapt to climate change. Trees for their vitality, safety and longevity can be maintained with the right skills to ensure. In the case of vegetation, reconstruction methods and solutions should consider the original layout and the constantly evolving ecosystem. For this reason, the first step in the restoration process is a long-term detailed study about the plant stock and its dynamics [36, 43].

Plants are continuously evolving and changing elements of a garden, so preserving them in a good condition requires constant maintenance. Trees become monuments with time because of their age, size, botanical value, and rarity, and must remain healthy for as long as possible [36]. Therefore, it is essential to renew the trees for generations to come, most appropriately based on the condition of the plant: it could be a complete replacement of the entire tree line, phased renovation, or replacement of one tree or group of trees.

All interventions must be planned in an informed and transparent way and implemented in a well-organised manner [42]. Financial planning and allocating the necessary resources should be the gardener's responsibility. Roles and responsibilities for trees should be clearly defined. For planning purposes, it is essential to keep accurate records of trees, their condition and number in a comprehensive database, which is regularly updated. A holistic approach to the restoration of historic gardens is well illustrated by the innovative research methodology of Gullino et al. (2020), which uses historical analysis to make recommendations for reconstruction and future sustainable management through knowledge of present values. The methodological framework and the definition of sustainable approaches that combine new needs and critical issues with composition and historical values are essential for the sustainability of historic gardens [44].

Climate change makes it challenging to preserve historically authentic tree planting. However, it is a priority to protect the existing significant individuals and prolong their life as long as possible. In the case of new plantings, the plan should focus on creating biodiverse vegetation with resilient species and minimise the negative effects on historical quality and integrity. Changes in plant palette may affect the planned initial aesthetics of plant compositions and alter the silhouettes or the colour compositions [19]. For historical compositional planting (such as tree lines, clumps, solitaire trees), consideration is vital in using species likely to adapt to future climatic conditions while retaining the original design and character. The approach may be more flexible in less historical significance the sustainability of historic gardens [11]. Keeping the original taxa can only be a priority in the most critical areas of the garden; otherwise, replacing them with the same taxon at all costs places such a heavy threat on the garden that it endangers long-term maintenance. In such cases, similar but more resistant taxa and cultivars similar in their habitus, crown form, leaf texture should be planted, which may have already been performed well in a challenging (drier, more polluted) environment.

There are regional tendencies in the vegetation changes [45, 46], which also affect the historic gardens' habitat and living heritage. Therefore, it is necessary and worthwhile to examine these trends in the case of a species change and draw conclusions for the given area and for the selection of the most suitable plant [39].

Besides planting design, garden maintenance methods need an overall development both in professional and financial aspects, to find an acceptable answer to climate change challenges. For the survival in a more continental climate, the increase of tree canopy might be helpful as a conditional tool, though the garden character might change dramatically. The Nagycenk historic garden is a living example of habitat changes due to severe interventions in natural water system. Garden renewal plans ought to concentrate on the contemporary ways and methods of on-site rainwater utilisation, especially in historic gardens where the mature tree canopy suffers from the drying climate.

In this respect, it can be said that both gardens under study contain a good number of specimens, the death of which would result in a serious loss of aesthetic and cultural value and, in addition, a significant decline in ecosystem services. These include, for example, the old oaks, linden trees and hornbeam hedge in the Széphalom garden, the giant sequoia, the sycamore trees in the grove, and the beautiful evergreen pines, topiaries, and colourful-leaved species in the Nagycenk garden. That is why the responsibility of the garden management for the living elements is also enormous. ⦿

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