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Future Role of Exotic Tree Species in Hungarian Built Heritage Environments

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Abstract: Although some exotic tree species, new to the country at the time, had already been introduced at the turn of the 18th and 19th century in the Hungarian landscape gardens, using foreign tree species in the space composition became widely popular only from the second half of the 19th century. This research focused on determining the date of appearance and compositional role of exotic trees in Hungarian landscape gardens. We can still find aged exotic woody taxa which determine the historical spatial structure in numerous landscape gardens nowadays. The nationwide distribution of these species, and their location within the gardens, can be an important addition to the questions of the revitalization of historical gardens, the more so because they may be indicative of the climate adaptability and, therefore, resilience of built heritage environments. An experimental approach to the introduction and use of new exotic tree species in historic gardens where this approach can be proven to have existed is also discussed as an opportunity to use these gardens in search of new foreign taxa to adapt to climate change.

Keywords: historic garden; landscape garden; plantation; garden composition; resilience; climate adaptation; experimental approach

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1. Introduction

The research about the use of exotic tree species in the spatial composition of Hungarian landscape gardens began fifteen years ago [1]. In Hungary, tracing the plant use of historic gardens of various eras before the landscape style (Mediaeval, Renaissance, Baroque) is only possible through archival research, because the majority of gardens established in those periods have been either destroyed or transformed. Moreover, due to the world wars and the political–social changes of the 20th century, much of the family archives of the aristocracy (owners of country estates and manors with gardens of historical value) have also diminished. The research was based on the hypothesis that today's existing landscape gardens provide living evidence about the use of plants from the time they were created.

One of the major contributions of the research lies in dating the first appearance of exotic trees in the composition of the Hungarian landscape gardens. This involved investigating the distribution and dominance of different species and their influence on the atmosphere and scenery of the gardens. The plant use in parts of Hungarian landscape gardens was based on the existing native plant communities. The vegetation of some gardens consists exclusively of native species. A number of gardens, however, possess exotic species in addition to the native ones, many of them trees. Some of the exotic tree species that were first brought into the country at the end of the 18th century and became widely popular during the 19th century still have living old specimens in historic gardens, demonstrating the long-term vitality of the imported woody plants under Hungarian climatic conditions. The trees of these gardens are the basic structural elements, the building blocks of the spatial composition. Their placing within the characteristic formal layout of

the various design styles is fundamental regarding the preservation and conservation of historical garden heritage.

The principles for the preservation of historic gardens as "living monuments" were first stated officially in the Florence Charter in 1981 [2]. Further considerations, such as adding other forms of historic urban greenery to the category of "historic gardens", were included in the ICOMOS-IFLA Document on Historic Urban Public Parks [3]. The importance of the framework created by these documents to the present research lies in the fact that the landscape gardens that host the exotic tree species either started out as country estates, remote from the noise and ills of the city, or were established with the intention to create public parks. Due to the urbanization processes of the past two hundred years, we find many of them enclosed and surrounded by urban development. Thanks to their environmental and cultural values, they form part of the historic urban landscape [4]. On the other hand, historic gardens are also an important element of the urban green infrastructure network which was pointed out by Marzanna Jagiełło in her article on the question of authenticity in the preservation of historic gardens [5]. (A few Hungarian examples are the historic gardens of Acsád, the Upper and Lower Gardens of the Grassalkovich palace in Gödöllő, and the historic public parks of Budapest (Orczy Garden, City park, etc.) as well.) The characteristics of the urban climate, coupled with the impacts of climate change and biodiversity loss, indicate that historic gardens, as an element of green infrastructure, might and will play a significant role in climate adaptation.

Based on the above, the following questions were governing the research on the use of exotic tree species in Hungarian landscape gardens:

1. What nationwide distribution of the studied species in landscape gardens can be mapped;
2. Whether there is a common pattern in the application of exotic species within the spatial composition of the studied landscape gardens;
3. What are the possibilities for applying exotic tree species in historic urban landscapes in the future.

2. Materials and Methods

The research consists of two major parts. The first is comprehensive garden historical research which provides the foundation for the second part, which is the on-site assessment of the gardens. As for garden research into Hungarian gardens outside the present-day borders, several studies have been made [6–19]. In the present paper, we review the research restricted to the territory of today's Hungary.

The examined time period extends from the end of the 18th to the very beginning of the 20th century. The historical research [1] was based on primary and secondary sources. Our primary sources mainly were texts and drawings from the state archives, and journal articles, whereas the secondary sources were printed literature (e.g., travelers' or others' descriptions of the country of the time). The relevant sources were collected and organized systematically. This paper only builds on the sources that unambiguously date the first appearance of exotic trees in certain landscape gardens.

The second part of the research is based on the field survey of the 77 landscape gardens that were selected based on the historical research. The location and arrangement of the existing aged exotic species within these gardens was recorded. A comparative analysis of historical maps (third military survey of the Habsburg Empire 1869–1887, cadastral maps of the Habsburg Empire 19th century) synchronized with contemporary satellite images allowed us to examine how the position and size of the landscape garden relative to its urban environment changed due to processes of urbanization, with a view to its present role in the green infrastructure of the settlement [20].

During the thorough garden historical research, the most popular foreign tree taxa mentioned in the reviewed literature and sources were collected together with dates of their introduction to landscape gardens in order to verify exact dates for some gardens concerning the appearance of certain tree species. In the case of several gardens, only general references are made in the sources to exotic trees, and there is not enough information

yet to specify which tree species are meant. In the case of other gardens, the name of the tree species is recorded, but without any reference to when they were planted. The year of publication of the summary works may provide some clues, but more in-depth research is needed to identify the species and the precise date of the plantation. This involves the preparation of a detailed and thorough conservation study for each garden, clearly not in the scope of the present research. A database of Hungarian historic gardens in the Carpathian Basin is under continuous development and can serve as the foundation for further detailed studies [21–24].

In some rare cases, both the actual exotic tree species and the date of plantation can be found. As regards actual sites in Hungary, the possibility to find garden historical sources is widely varied. Hardly any data can be found in some cases owing to the devastation of the two world wars and the communist regime. Still, there are venues about which a wealth of historical data survive. The present paper may provide a point of departure for detailed garden historical research, at least concerning the plant use and plant composition in Hungarian landscape gardens.

In the analyzed 77 Hungarian landscape gardens, the space compositional role of the exotic trees was unequivocally detectable. (In the case of Tura, the experiences of the 2011 survey were supported and backed by a tree stand survey and analysis conducted by Pagony Táj- és Kertépítész Iroda in 2016 [25].) During the survey of the gardens, the current plant stock was assessed with special emphasis on the distribution of the aged (at least a century-old) exotic woody species within each garden. To estimate the age of the trees quickly and without complex instruments, Radó's empirical method was used, calculating it from the trunk's diameter [26]. The role of the exotic tree species in shaping the character of a landscape garden was assessed qualitatively, based on the site surveys. The effect of exotic tree species on the character of the garden is twofold: 1. The diversity of exotic species determines the atmosphere of the garden view; 2. The reappearance of one or a few exotic species gives a special character to the garden. The dominant role of exotic tree species within a garden is unanimously verified by two aspects. One is the great variety of exotic tree species; the other aspect is the high number of specimens of one or just a few old exotic tree species in the gardens.

The Arcanum Maps, available online, were used to detect changes in the relationship between the 77 landscape gardens and their respective built surroundings during the past 150 years [20]. The synchronized view of the historical maps and the contemporary satellite images made the comparison possible. The concept of the analysis is visualized on Figure 1. The diagram shows a simplified typology of the possible relationship of historic garden and settlement, and the types of changes recorded.

The frequency of the types of arrangement of exotic species in the landscape gardens and the frequency of the typical changes of the role of the landscape gardens in the urban green infrastructure network were calculated. Statistical analyses (Chi^2 and Z tests) were used to compare the observed proportions and the theoretical proportions (0.333 for the Chi^2 test and 0.5 for the Z tests). The expected values were all above 5. Statistical evaluation was performed using IBM SPSS v27 and Microsoft Excel [27,28].

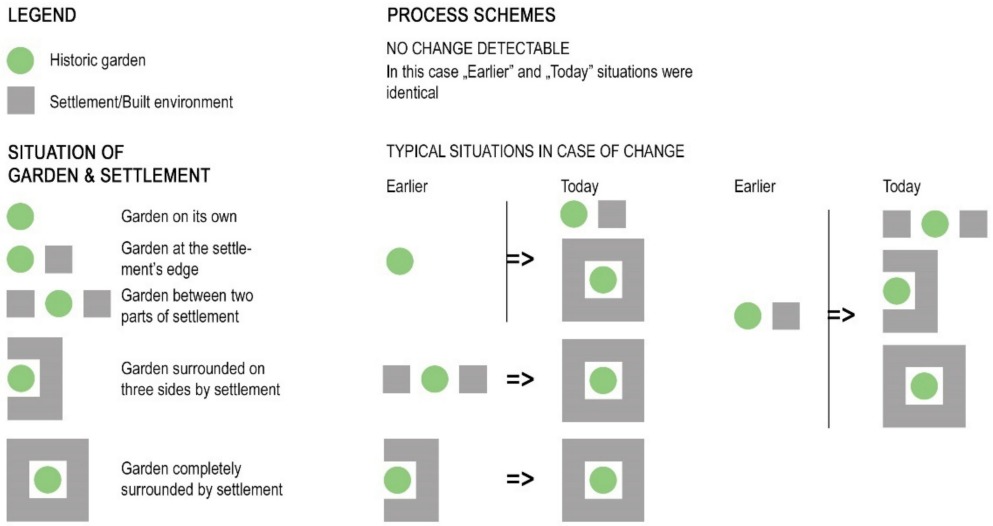

Figure 1. Schemes of the relationship of garden and settlement based on the comparison of historical maps ("Earlier") and satellite images ("Today"). (Figure: M.S.).

3. Results

3.1. Historical Research

Many publications deal with the use and distribution of exotic plants brought to European historic gardens, mainly from North America and Asia. These works discuss the topic usually from a botanical or a garden historical approach [15,29–33].

Instead of embarking on the garden historical research in detail, a few facts revealing the importance of the theme ought to be pointed out. The earliest appearance of the landscape garden in Hungary is dated to the end of the 18th century [34] (p. 149) and [35]. Bernhard Petri, an Austrian-born garden designer who was commissioned to design several landscape gardens in Hungary, wrote about his works for gardening enthusiasts in handbooks. He gives a detailed description of four landscape gardens in 1797, three of which—the Orczy Garden in Pest, the Garden of Vedrőd (today Voderadi, SK) and the Hédervár Garden—he labelled "nature-like" ("Naturgarten") [36–38]. (The fourth, smaller garden—that of Ásványráró (extinct today)—was founded in 1794. Petri used the term "rural garden" ("landlicher Garten") to describe it [39].) He used the indigenous plants of the Hungarian landscape for his gardens, strikingly imitating nature, yet organized upon calculated aesthetic effects. This can be known from the list of plants he attached to his book [36] (p. 135), [37] (pp. 156), [38] (p. 75), and [40]. Petri's writings also reveal that he knew several woody taxa because he mentioned them in a description of a botanic garden abroad, which had been, so far, new to Hungarians. In the ducal botanic garden of Pfalz-Zweibrücken, experimentation had been going on for years to domesticate several foreign tree species, e.g., *Ginkgo biloba*, *Gleditsia triacanthos*, *Gleditsia inermis*, *Fagus sylvatica* 'Atropunicea', *Catalpa bignonioides*, *Cercis siliquastrum*, *Juglans nigra*, *Liriodendron tulipifera*, diverse magnolias, and *Platanus* × *acerifolia* [41].

As it is well known, members of the Hungarian aristocracy regularly toured European countries and had an insight into the tastes, gardening habits, and botanic novelties of the age. In 1818, the English traveler Richard Bright acknowledged the aesthetic quality of Hungarian landscape gardens when he noted that strolling one morning in the park of the Brunswick mansion in Martonvásár (designed by Heinrich Nebbien; see Figure 2), the surrounding garden made him feel as if he were at home in England [42] (p. 609). At the time, garden owners, garden architects, botanists, writers, poets, and other representatives of the culture were in a network of relations with one another. The botanists helped the aristocrats acquire novel plants or their seeds [43] (p. 53). It was typical of the age that botanists were keen on exchanging newer and newer plants they had become familiar with through their multiple international contacts [44] (p. 118). On the basis of foreign

tree species described in Petri's book, it can be inferred that the elite of the Hungarian garden owners knew exotic woody taxa not only as plant species but also as "building blocks", fully-fledged specimens of which were integrated in the spatial compositions of certain foreign gardens. The Hungarian botanist and director of the oldest botanical garden in Budapest, Pál Kitaibel (1757–1817), for instance, had an exchange network in France, Germany, Switzerland, Austria, and Italy that suggests he may also have been familiar with the woody taxa known around Europe [45] (p. 87) and [46]. A long list of exotic tree species dated to 1808 names the stock in the so-called Tree Garden (*Fás Kert*) of the Festetics-mansion Park in Keszthely [47]. A plan drawing of this garden by János Szajdensvartz [48] dated to 1807 shows the formal features of this ir-regular garden which is a transitional style between the baroque garden and the landscape garden. This dendrological collection also functioned as a teaching aid for the agricultural school called *Georgikon* founded by György Festetics in 1797 adjacent to the Festetics-mansion Park [43] (p. 53). The Tree Garden's collection of trees received a subtler, more mature landscape design in the first half of the 19th century. At that time, it was physically united with the spatial layout of the mansion park; therefore, similarly to some English landscape gardens (e.g., Chatsworth, see Figure 3), the tree corpus was integrated in the overall formal composition of the garden as a separate functional unit [49].

In comprehensive works, little is said of concrete locations when plants are discussed, but information can still be gleaned about several venues. The earliest mention is made of Nagycenk, but instead of naming concrete plants in his monograph, the author refers to the employment of a large number of varied foreign tree species [35] (p. 386). Even though written sources can be found with reference to the use of exotic trees in some Hungarian landscape gardens before the 19th century, their taxa and date of planting is not known. As shown above, specific tree species are only mentioned starting from the beginning of the 19th century. Some sources even provide the date of planting as well. One of them is the academic inaugural address of baron Gábor Prónay mentioning several species and locations, one of them being the ginkgo in Acsa planted in 1808 [50]. Although he speaks of Acsa (Pest County), he may have meant Acsád (Vas County), since a considerable-sized ginkgo specimen can still be found there. An article written in 1890 reveals that the foxglove-trees (*Paulownia tomentosa*) of the archbishop's palace park in Kalocsa and the park of the Batthyány mansion in Ikervár were said to be a hundred years old [51] (p. 284). Though the exact age of these specimens cannot be determined, it is fair to conclude that they were planted in the beginning of the 19th century. It is learned from the same article that the Palatine Joseph planted a plane-tree (*Platanus* × *acerifolia*) sapling in Margaret Island, Budapest, himself in 1823 [51] (p. 283). Among the tree species of the Buda castle park, productive *Ginkgo biloba* specimens are mentioned beside *Fagus sylvatica* 'Atropunicea' and *Gymnocladus dioicus* [52] (p. 222). Since several decades may pass before a ginkgo bears fruit, these specimens were probably planted at the onset of the 1800s. Concerning Sárvár, Szécsény, and Széphalom, tree species can be linked to exact dates [53] (p. 14), [54] (pp. 947–951), [55], [56] (p. 86), and [57]. Regarding Széphalom, Figure 4 contains the tree species that the Hungarian writer and poet Ferenc Kazinczy partly had in his garden and partly knew of (gray text in Figure 4). Some of the abovementioned data prove that by the beginning of the 19th century, these exotic tree species were known all over the country within today's borders (see Figure 4 showing dates with the located exotic species).

Figure 2. Martonvásár, Brunswick-mansion Park in 2016 (Nr.38 in Table 1). (Photo: M.S.).

Figure 3. The plant collection part of the Chatsworth landscape garden in 2011. (Photo: M.S.).

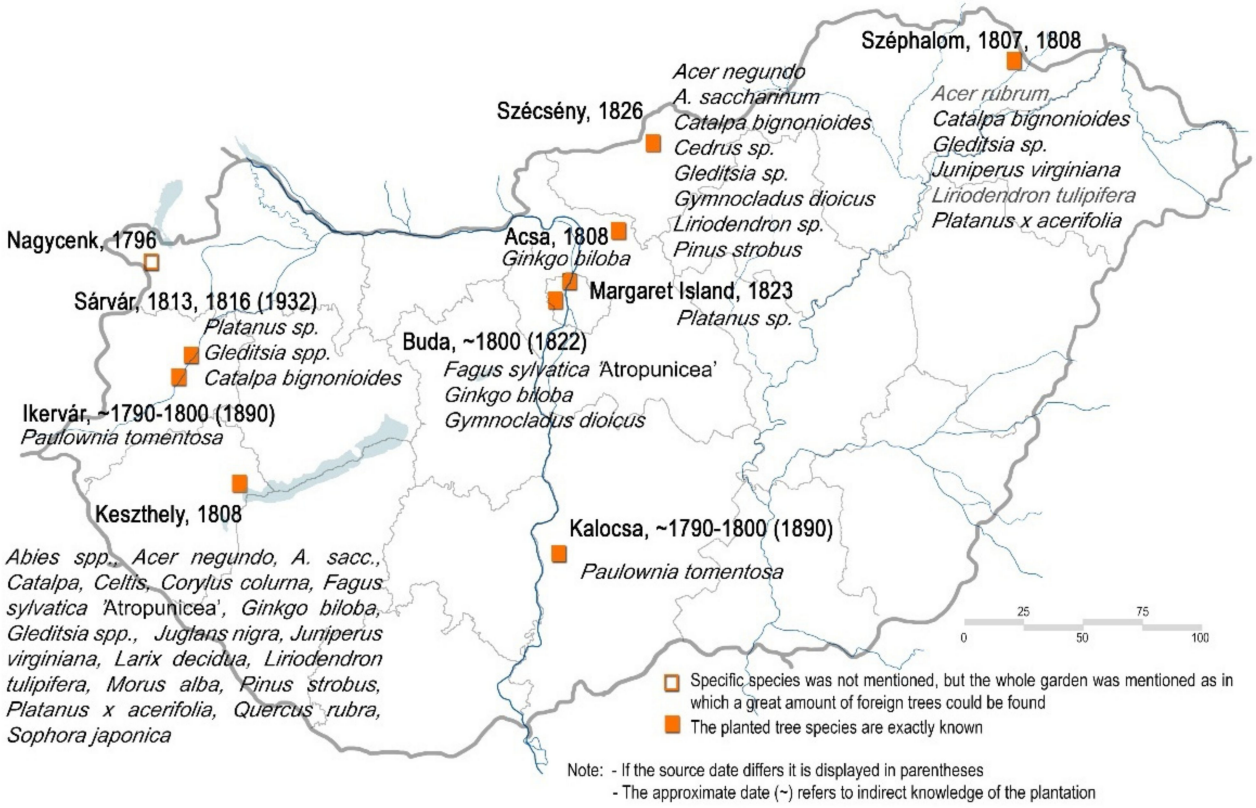

Figure 4. Knowledge of the very early use of exotic tree species in Hungary on the basis of written sources. (Data sources in the main text; figure: M.S.).

3.2. Field Surveys

The aim of the field surveys was to update the garden list compiled from the historical research with on-the-spot inspection. The assessment of the actual situation included a survey of the layout of each garden and the exploration of the role of old exotic woody taxa determining the spatial composition. Although the majority of the trees mentioned in the written sources can no longer be found at the referred locations, the aged tree giants found in the present stands give a reliable representation of the geographical distribution of the applied exotic species. Based on the written and cartographic sources, and the findings of the site surveys, 77 landscape gardens were found, in which the spatial composition was undoubtedly determined by exotic woody taxa. (See Figure 5 and Table 1; and some examples: Figures 2 and 6–8). The surveys revealed the most popular tree species, that is, those that occurred in at least twenty landscape gardens. Among the deciduous trees, the following thirteen species were found in most gardens (the number in parentheses indicates the number of gardens, out of the 77, in which the given species was found): *Aesculus hippocastanum* (47), *Catalpa bignonioides* (23), *Fagus sylvatica* 'Atropunicea' (41), *Ginkgo biloba* (41), *Gleditsia* spp. (24), *Gymnocladus dioicus* (25), *Juglans nigra* (29), *Liriodendron tulipifera* (37), *Magnolia* spp. (34), *Platanus x acerifolia* (67), *Quercus robur f. fastigiata* (33), *Quercus rubra* (27), *Sophora japonica* (34). From the Pine (*Pinaceae*)-, Cypress (*Cupressaceae*)- and Yew (*Taxaceae*) families the following six were dominant: *Abies* spp. (31), *Pinus nigra* (40), *Pinus strobus* (21), *Pseudotsuga menziessii* (20), *Sequoiadendron giganteum* (26), and *Taxodium distichum* (22).

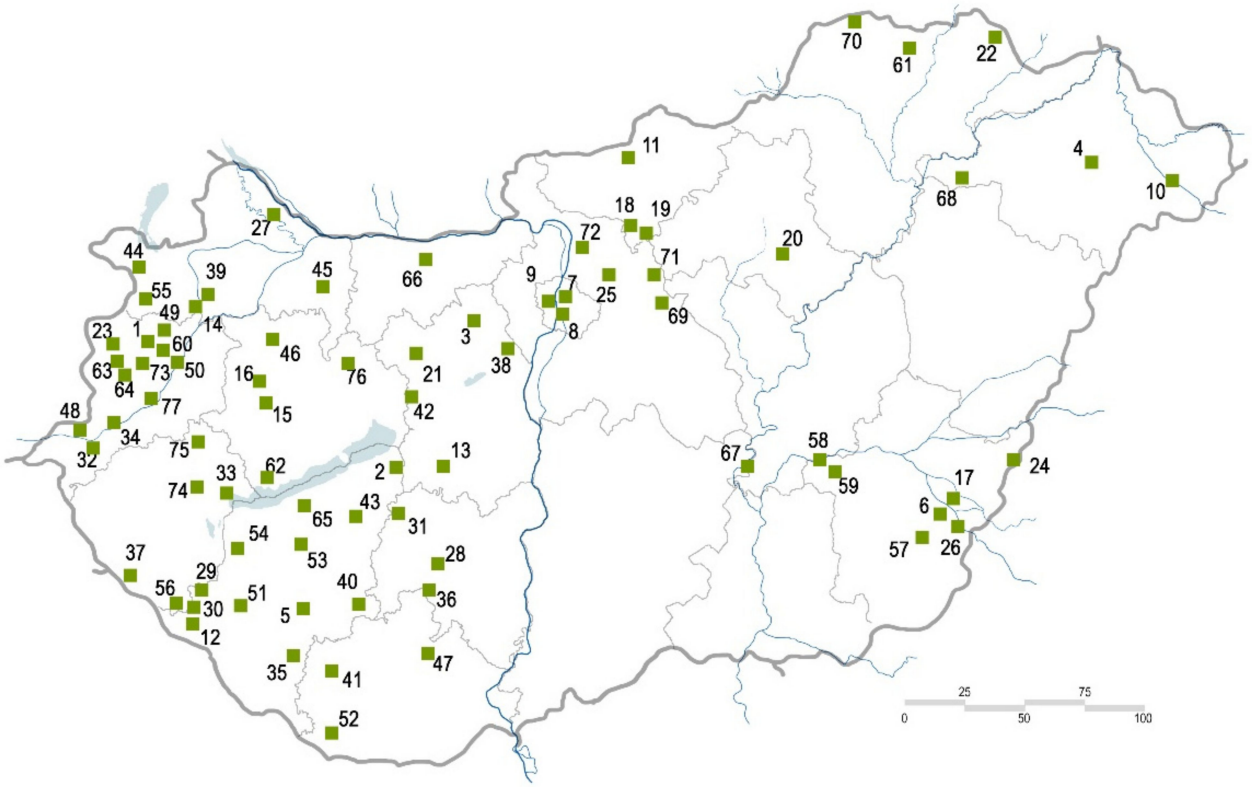

Figure 5. Location of the 77 landscape gardens. (Figure: M.S.).

Figure 6. Dég, Festetics-mansion Park in 2015 (Nr.13 in Table 1). (Photo: M.S.).

Figure 7. Pápa, Esterházy-mansion Park in 2013 (Nr.46 in Table 1). (Photo: M.S.).

Figure 8. Tornanádaska, Hadick-mansion Park in 2012 (Nr.70 in Table 1). (Photo: M.S.).

Table 1. Result of the field survey (2014). List of landscape gardens in which the old exotic tree species had a significant role in the space composition.

Place and Name of Landscape Garden	Arr. Type *	Place and Name of Landscape Garden	Arr. Type *	Place and Name of Landscape Garden	Arr. Type *
1. Acsád, Szegedy-mansion Park	B	27. Hédervár, Khuen–Hédervári-mansion Park	C	53. Somogyvár, Széchenyi-mansion Garden	A
2. Ádánd, Csapody-mansion Garden	A	28. Hőgyész, Apponyi-mansion Park	C	54. Somogyzsitfa, Véssey-mansion Garden	A
3. Alcsútdoboz, Palatine Joseph's mansion Park	B	29. Iharos, Inkey-mansion Garden	B	55. Sopronhorpács, Széchenyi-mansion Park	B
4. Baktalórántháza, Dégenfeld-mansion Park	B	30. Iharosberény, Inkey-mansion Garden	B	56. Surd, Zichy-mansion Park	B
5. Bárdibükki, Country House Garden	B	31. Iregszemcse, Kornfeld–Viczay-mansion Garden	A	57. Szabadkígyós (former Ókígyós), Weinckheim-mansion Park	A
6. Békéscsaba-Gerla, Weinkcheim-mansion Park	B	32. Iváncsa, Sigray-country house Garden	A	58. Szarvas, Bolza-garden (today Arboretum of Szarvas)	B
7. Budapest, City Park	C	33. Keszthely, Festetics-mansion Park	A	59. Szarvas, Bolza-mansion Park	B
8. Budapest, ELU Botanical Garden, one-time Festetics-mansion Park	B	34. Körmend, Batthyány-Strattmann-mansion Park	B	60. Szeleste, Baich–Szentgyörgyi–Horváth-mansion Garden	B
9. Budapest, Margaret Island landscape Park (once park of the archdukes and palatines)	C	35. Lad, Hoyos-mansion Park	A	61. Szemere, Szemere–Pallavicini-mansion Garden	B
10. Cégénydányád, Kölcsey–Kende Country House Garden	B	36. Lengyel, Apponyi-mansion Park	A	62. Szigliget, Esterházy-mansion Park	C
11. Csitár, Majláth-mansion Garden	A	37. Letenye, Andrássy–Szapáry mansion Park	B	63. Szombathely-Kámon, Saághy-kúriakert (today Arboretum of Kámon)	B
12. Csurgó, Garden of Csokonai V. M. Grammar School	A	38. Martonvásár, Brunswick-mansion Park	C	64. Szombathely-Szentkirály (former Bogát), Festetics-mansion Park	B
13. Dég, Festetics-mansion Park	A	39. Mihályi, Dőry-mansion Garden	B	65. Szőlősgyörök, Jankovich-mansion Garden	B
14. Dénesfa, Cziráky-mansion Park	A	40. Mosdós, Pallavicini-mansion Garden	A	66. Tata, English Garden	C
15. Devecser, Esterházy-mansion Park	B	41. Mozsgó, Batthyány–Biedermann-mansion Park	B	67. Tiszakürt, Bolza-mansion Garden	A
16. Doba, Erdődy-mansion Park	C	42. Nádasdladány, Nádasdy-mansion Park	B	68. Tiszavasvári, Dessewffy-mansion Park	B
17. Doboz, Weinckheim-mansion Park	B	43. Nágocs, Zichy-mansion Park	A	69. Tóalmás, Andrássy-mansion Park	C

Table 1. *Cont.*

Place and Name of Landscape Garden	Arr. Type *	Place and Name of Landscape Garden	Arr. Type *	Place and Name of Landscape Garden	Arr. Type *
18. Erdőtarcsa, garden of former country house	B	44. Nagycenk, Széchenyi-mansion Park	B	70. Tornanádaska, Hadick-mansion Park	B
19. Erdőtarcsa, garden of former Kubinyi–Márkus-country house	A	45. Pannonhalma, Benedictine Arboretum	B	71. Tura, Schossberger-mansion Park	B
20. Erdőtelek, Buttler–Kovács-mansion Garden	B	46. Pápa, Esterházy-mansion Park	C	72. Vácrátót, Vigyázó-mansion Park	B
21. Fehérvárcsurgó, Károlyi-mansion Park	A	47. Püspökszentlászló, bishop's castle Park	B	73. Vép, Erdődy-mansion Park	A
22. Füzérradvány, Károlyi-mansion Park	B	48. Rátót, Széll-mansion Park	B	74. Zalacsány, Malatinszky–Batthyány-country house Garden	B
23. Gencsapáti, Széchényi–Erdődy–Széchenyi mansion Park	A	49. Répceszentgyörgy, Szentgyörgyi–Horváth-mansion Garden	A	75. Zalaszentgrót, Batthyány-mansion Park	C
24. Geszt, Tisza mansion Garden	B	50. Sárvár, Bavarian archducal Garden	B	76. Zirc, landscape Garden of the Cistercian Abbey	B
25. Gödöllő, Upper Garden of the Royal Palace	A	51. Segesd, Széchenyi-mansion Park	A	77. Zsennye, Bezerédj-mansion Park	A
26. Gyula, Almássy–Wenckheim-mansion Garden	B	52. Sellye, Draskovich-mansion Park	A		

* Arrangement types: A—gradational; B—homogeneous; C—dominant.

4. Discussion

4.1. Nationwide Distribution of Exotic Tree Species

In gardens enriched with dendrological specialties, several regularities could be observed (some of the results have already been published, see [58]) in applying certain tree species, but their discussion does not belong strictly to the present theme.

The location of the 77 gardens in which the abovelisted tree species were observed in a higher concentration was plotted in maps (Figure 9). It can be observed in Figures 5 and 9 that in the eastern part of Hungary, landscape gardens having exotic trees are much rarer than in other parts. Our study does not venture to give an explanation for this. Research about the influence of historical as well as landscape historical changes examined in collaboration with other disciplines (e.g., geology, hydrology, meteorology, dendrology, and geography) may result in discovering the reasons why certain species survived where they can be found today. Just one remark about the map on Figure 9A can serve as an example: the gardens in which a great variety of *Pinus* species appear are located mostly on hilly or mountainous areas where the annual precipitation is at least 600–650 mm, which might be enough for the pine species to tolerate our climate. By the same token, it is to be borne in mind that most landscape gardens were formed by using the already existing gallery forests in flood plains where water supply was sufficient.

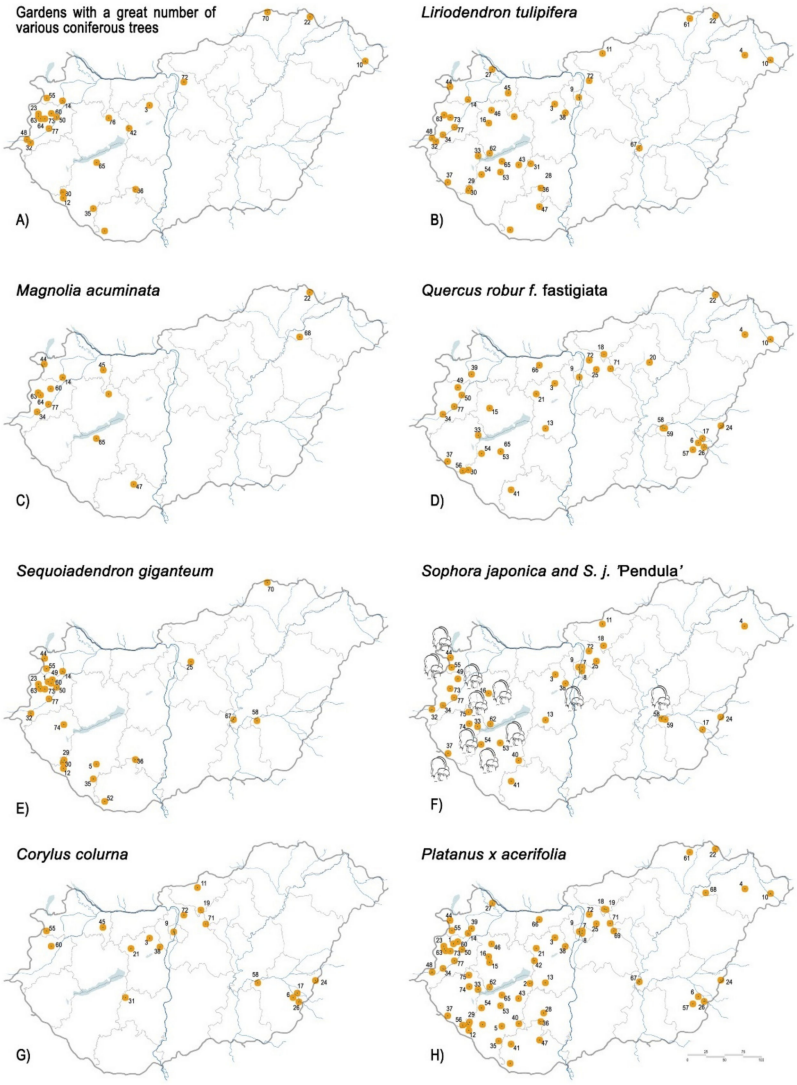

Figure 9. Distribution of some popular exotic species in the investigated gardens. (Figure: M.S.).

The main reasons for the manner in which exotic tree species were distributed within the country may include, among other factors, the following:

Possibilities (in the mode of spreading):

- Travels of the owner abroad (acquisition of plants);
- Contacts with family, relatives, and friends (exchange of plants).

The most critical challenge to the domestication of exotic species in Hungary was their sensitivity to frost. Successful protection of the young plant from frost was essential, as the winters of that time could be extremely cold for longer periods.

4.2. Arrangement of Exotic Species in the Spatial Structure

During the field surveys, the arrangement and spatial position of exotic species within each garden were examined. The main finding of this investigation was the three decisive types [1] of arrangement in the mentioned 77 surveyed gardens. A fundamental characteristic of landscape gardens is their intention to seamlessly dissolve into their broader environment. The designer's aim is to give less and less importance to exotic tree species as we move in the composition towards the boundaries of the garden, giving way to the dominance of native species. The typology, to be unfolded further on, approaches this question from the spatial composition experienced today. Therefore, on the one hand, it proves the known intention of the designer (gradational arrangement); on the other hand, it

points out arrangement types so-far undiscussed in terms of Hungarian landscape gardens. The latter types may well be regarded as original design concepts, looking at them from the evidence of the site surveys. According to the terminology, the types of spatial arrangement are: gradational, homogeneous, and dominant arrangement. Figure 10 shows the schematic distribution and the proportion of the exotic trees in the different types of arrangements.

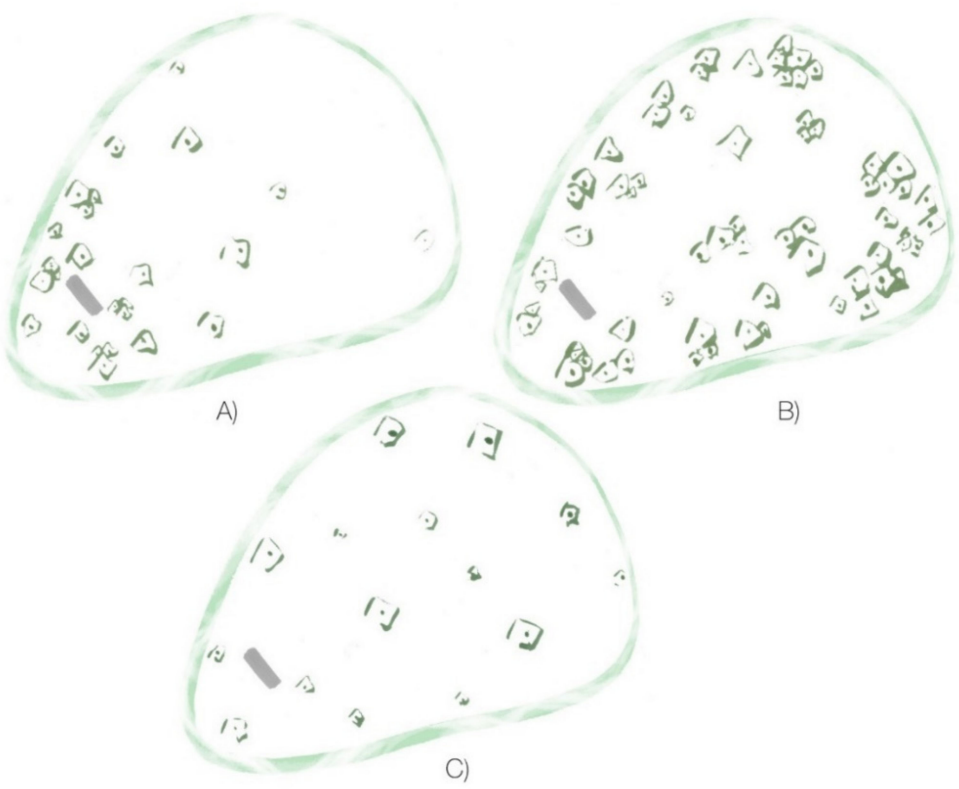

Figure 10. The different types of spatial arrangement: (**A**) gradational arrangement, (**B**) homogeneous arrangement, (**C**) dominant arrangement. (Figure: M.S.).

Gradational arrangement (Figure 10A): This layout is well known in garden history. In this layout, the exotic tree species become gradually fewer and farther between as their distance from the country house increases, and approaching the borders of the garden, they are gradually replaced by native species (e.g., Festetics-mansion Park in Dég (nr. 13); Hoyos-mansion Garden in Lad (nr. 35); Apponyi-mansion Park at Lengyel (nr. 36); Zichy-mansion Garden at Nágocs (nr. 43); Széchenyi-mansion Garden, Somogyvár (nr. 53); Ókígyós, Wenckheim-mansion Garden (nr. 57)).

A layout is homogeneous (Figure 10B) when in a landscape garden the exotic species are spaced out relatively evenly (they have a constant density) (e.g., Acsád, Szegedy-mansion Garden (nr. 1); Palatine Joseph's Garden in Alcsútdoboz (nr. 3); Széll-mansion Garden in Rátót (nr. 48); Zichy landscape garden, Surd (nr. 56); Baich-Szentgyörgyi-Horváth-mansion Garden in Szeleste (nr. 60); Garden of the Zirc Abbey (nr. 76)).

The arrangement is dominant (Figure 10C) when an exotic tree species determines unambiguously the character of a garden as a leading, or at least dominant, species owing to its large number of specimens, and appearing at diverse points of the garden as a repetitive element in the garden composition (e.g., Apponyi-mansion Garden in Hőgyész (nr. 28); Brunswick-mansion Park in Martonvásár (nr. 38); Esterházy-mansion Garden of Pápa (nr. 46); Batthyány-mansion Garden, Zalaszentgrót (nr. 75)).

Regarding the arrangement, out of the 77 landscape gardens, 25 (32.5%) belong to the gradational, 41 (53.2%) to the homogeneous, and 11 (14.3%) to the dominant type. The homogeneous arrangement type is significantly more frequent, whereas the dominant arrangement type is significantly less frequent than the gradational type (Ch^2 (2) = 17.558;

$p < 0.001$) among the landscape gardens with exotic species. In Figure 11 the location of the examined landscape gardens and their respective arrangement types are mapped. Table 1 provides the place, name, and arrangement type of the landscape gardens.

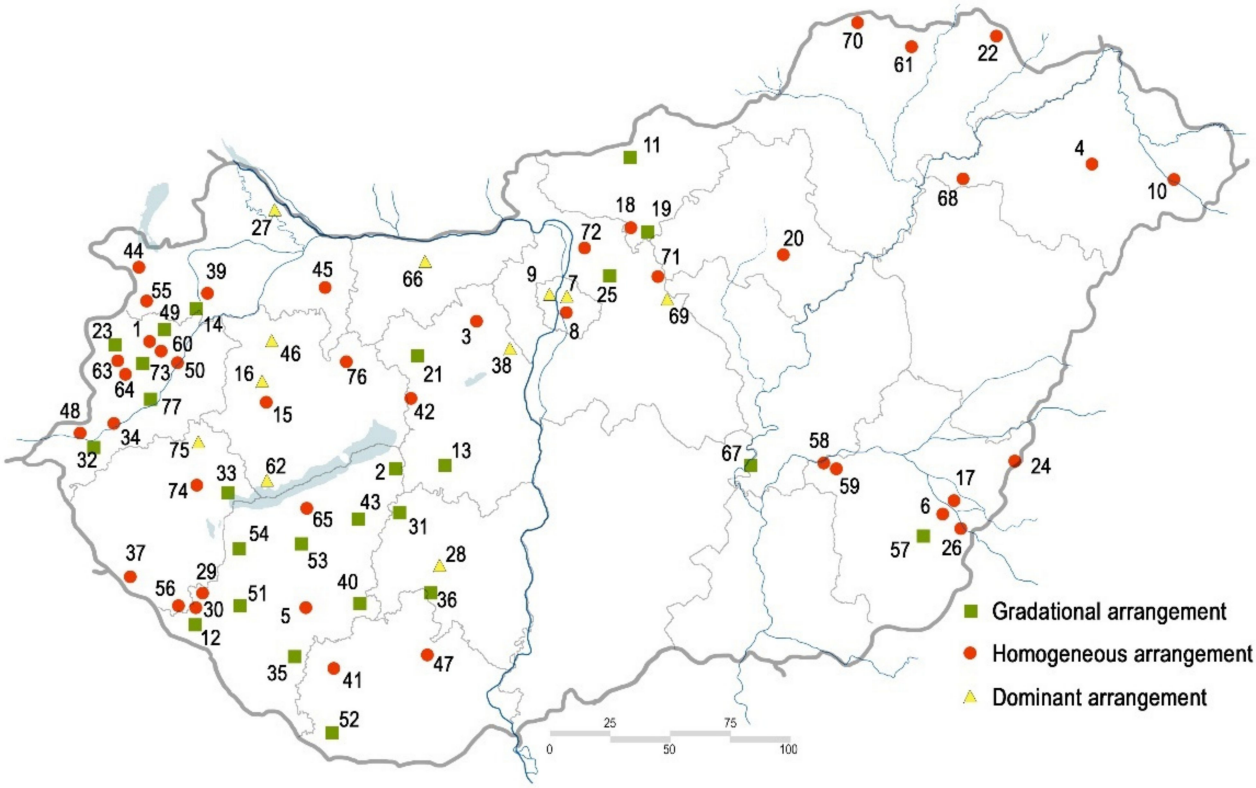

Figure 11. Distribution of the landscape gardens by the different arrangement types. (Figure: M.S.).

Having compared the past garden sizes specified during the historical research to the respective figures of the present-day situation, it was found that in the case of 62 of the 77 studied gardens (80.5%), the size of the grounds did not decrease. The statistical test revealed that the landscape gardens whose size remained unchanged can be found in a significantly larger proportion than those whose size had decreased ($Z = 5.36$; $p < 0.001$). This is important because during the 20th century, the ownership, and consequently, the function of Hungarian historic gardens radically changed from private to state property. As a result of the disrespect for the values of the unwanted aristocratic elite, in some cases, the area of the gardens was divided and reduced, or even completely consumed. Based on the above comparison, it can be concluded about these sixty-two gardens that the arrangement types also reveal the one-time distribution of the exotic tree species in the spatial composition, and as such, they can be taken for consciously intended design or planting versions.

4.3. Position of Landscape Gardens within Settlements

Examining the location of the landscape gardens within their contemporary built environment provides information about their role and future importance in the urban green infrastructure network. The relevance of this question is that a diverse and connected network of green spaces in the built environment is a key to respond to the challenges of the changing climate [59]. This is due to the fact that their microclimate is usually more comfortable than elsewhere in the built environment, and, among others, they have a capacity to absorb, transpire, and, at times, store stormwater. Green spaces (of which landscape gardens also form a part) are considered a nature-based solution, and as such, they are strategic tools for climate adaptation [60].

Out of the 77 surveyed landscape gardens, in 33 cases (42.8%), the relationship between the settlement and the garden experienced no change in the past decades. That is, as the settlements developed and grew, these historic green spaces kept their original place in the settlement structure. No statistically significant pattern can be found here; the likelihood of change of relationship is the same as that of no change ($Z = 1.25$; $p = 0.21$).

Out of the 33, only 2 gardens (Doba and Zsennye) remained without a connection to the settlement. The statistical test proved that the gardens that do have a connection to the built fabric are significantly more frequent ($Z = 8.32$; $p < 0.001$) than the ones without a connection. In six cases (Mozsgó, Szarvas-Bolza garden, Szemere, Mihályi, Pannonhalma, and Csurgó), the gardens had been surrounded by the settlement right from the beginning, making the location of the gardens within the settlements particularly valuable, both from the point of view of heritage protection, and that of urban ecology. In the remaining 44 cases, the gardens became more closely connected to their respective settlements, several of them becoming completely enveloped by the built environment. Apart from three locations (Békéscsaba-Gerla, Gyula, and Tiszavasvári), this does not mean that the historic gardens underwent major transformations; the built fabric merely embraced them, and streets separate them from it. The proportion of landscape gardens where no transformation took place is significantly higher ($Z = 6.22$; $p < 0.001$) than that of those that were transformed in the 20th century. Conclusively, 50 (64.9%) of the 77 surveyed landscape gardens can be described as having an exclusive structural role in the settlement, which is a significantly higher proportion ($Z = 2.62$; $p < 0.01$) than that of those where no close connection was experienced. This proves that landscape gardens with exotic species are an important and special part of their respective urban green infrastructure network, representing values of heritage and urban ecology, as well as having the function of adapting the built environment to climate change.

4.4. Further Application of Exotic Species and Opportunities to Introduce New Ones

Most of the abovementioned exotic species have proven to be fit and adapted to the existing environmental conditions of the surveyed landscape gardens; however, precaution may be needed when further using them. In the case of some of these species (e.g., *Aesculus hippocastanum*, *Platanus* × *acerifolia*) [61], we have already experienced an increase in pests and diseases in the past 20 years. Restoring the historical spatial composition using the same vulnerable species raises serious concerns of management in the form of the cost and labor need of the protective and preventive measures, which in turn has an impact on the long-term economic operation and sustainability of the project. In these cases, a substitute must be found to the original species. As certain taxa, due to their unique visual character, are difficult to be substituted, this remains a challenge for each conservation project.

Arguably, vulnerability is an issue of the plant stock of landscape gardens. Climate change-related risks such as drought, the appearance of new pests and diseases, and storm damages may be the cause of loss in the tree stands. This makes the gradual renewal of the vegetation of landscape gardens a key task of heritage conservation as well as urban ecology. Using the historically appropriate native and exotic species will enrich the diversity of the garden's vegetation, contributing to its greater resilience to future risks.

The presence of aged exotic species in landscape gardens also offers the opportunity to further experiment with the introduction of new exotic species to the garden, to test their adaptability to the local conditions, as well as to find so-far unused species that can be applied as "imitations" of other taxa that are becoming harder to cultivate under the changing climatic conditions [62]. It is an idea inherent to the concept of the landscape garden as a collection of mementos from distant places, and a collection of plant compositions evoking various atmospheres and emotions, provided that exotic trees were originally included in the garden composition. Therefore, in those landscape gardens, where exotic tree species can be found, it can be regarded as the continuation of the spirit of historic garden heritage to design and manage the experimental introduction of new exotic species testing their vitality and viability under Hungarian climatic conditions. The expected impacts of climate

change (and urban climate) call for heat- and drought-tolerant species that do not require excessive irrigation. However, the invasive tendency of the new species must also be carefully considered and monitored to avoid the unwanted spread of the species.

The arrangement typology described above may form the basis of the planting scheme of the new exotic tree taxa within the landscape gardens. That is, by continuing the historical precedent of the gradational, homogenous, or dominant arrangement where appropriate, the newly introduced species would fit into the original design intention.

This experimental approach to the use of novel foreign species in the context of landscape gardens should form the basis of further research. It should of course be strictly aligned with the principles of the conservation of historic gardens. In Hungary, there are a number of historic gardens that lack the sources that would enable a thoroughly authentic restoration. These gardens could host and be the location for the experimental application of so-far unused species. This does not only have significance from a garden historical aspect, but also from a landscape and urban ecological point of view, with the possibility of finding new tree species that are adaptable to the changing environmental conditions of the built environment.

5. Conclusions

For the revitalization of historic gardens, it is imperative to know what plants were used in general (nationwide) and in the actual garden in question at the time of the studied garden historical period (Figure 4). The surviving aged tree specimens are authentic sources of a previous era's spatial structure of the garden. With their help, the overall space organization can be learned. This has particular significance when there is a lack of written sources. The assessment of aged tree species also gives clues as to their distribution within the country, which reveals how popular and widespread a species used to be and also indicates how successfully certain species were domesticated. The discussed research results about the application of exotic woody plants in historic gardens may give considerable help for the authentic revitalization of landscape gardens.

Undoubtedly, exotic tree species played an important role in the space layout of landscape gardens. Historical investigations, and often the present structure of the garden, indicate a dilemma of design that lies in the use of exotic novelties in the greatest possible number and diversity of species and specimens, versus the magnanimous arrangement of the overall space so inherent in the landscape garden. This can be attributed to the fact that for want of experience, the actual size of a dendrological curiosity was not known in the Hungarian climate, since planting something under different climatic conditions may cause the specimens to develop differently. Excessive interest in trees was often to the detriment of the space composition of the entire garden, cutting it into segments. It cannot be denied, however, that the reasonable application of exotic tree species enriched the gardens with peculiar, so-far unknown aesthetic qualities pointing beyond the formal curiosity of the specimens. Hungarian landscape gardens earned a special flavor either from the use of a leading exotic species or from a finely balanced combination of exotic and indigenous species. Combining exotic tree species with native species in good taste and proportion is still a challenge for professional, well-trained landscape architects, too.

The revitalization of landscape gardens may offer the opportunity to experiment with the domestication of so-far unused, new exotic tree species. The garden context being different from that of a tree nursery, one of the abovedescribed three spatial layouts (arrangement types of the exotic trees) would guide the placing of the new exotic species. To move this approach forward, further research is needed as follows.

- Garden-specific historical and archival research about the applied exotic species, determining the date of their first planting, their role in the spatial layout, and the atmosphere of the landscape garden. This may be viable particularly in the case of gardens whose proprietor family were known for their botanical interest, such as the Festetics, Sáághy, Bolza, Vigyázó, and Erdődy families, and the Palatine Joseph (see their gardens in Table 1).

- Dating the first introduction of exotic woody species based on the list in Section 3.2. would provide additional historical data about certain periods of the Hungarian landscape garden.
- An interdisciplinary research project about the influence of social, environmental, economic, and landscape historical changes to shed light on the reasons why certain species survived in the locations they can be found today (e.g., with the involvement of archeology, sociology, geology, hydrology, meteorology, dendrology, and/or geography).
- Defining the landscape gardens that could be locations of the controlled experimental introduction of new exotic tree species, as part of a future conservation project, with a description of the character (shape, color of foliage, deciduous/conifer, etc.) of the new species, based on the historically verified arrangement type, and the modeling of future environmental and climatic scenarios [62] specific to those gardens, in order to adapt to the changing climatic and environmental conditions of the built heritage.

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