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# Assessment of Supercell Storm-Induced Uprooting of Amenity Trees—Monetization of Environmental and Socio-Economic Losses

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**Abstract:** Amenity trees contribute to the overall quality of urban environments and are valued for their beauty and the benefits they bring to communities. However, the assessment of this capital commonly concludes with considerations of its vitality and decorativeness. Thus, this research provided a monetary assessment of losses caused by the supercell storm-induced uprooting of trees growing in three public green spaces utilized by the most vulnerable population (children aged 3–18 years). For these purposes, the Council of Tree and Landscape Appraisers (CTLA) formula was applied taking into account growth parameters, species dependence, and the specimens' condition and location. Prices from national and European nurseries were utilized to obtain appropriate base values. The results indicate that the total appraised monetary loss amounted to EUR 495,864 (national) and EUR 1,528,481 (European prices). The species *P. nigra*, *B. alba*, *T. tomentosa*, *F. excelsior*, *A. saccharinum*, *P. occidentalis*, and *P. cerasifera* showed lower uprooting resistance with no clear species-specific responses, but there was an interaction of biotic, abiotic, and artificial influences. Understanding the complex factors influencing tree stability is crucial for urban planners and arborists to mitigate storm- and wind-related risks. Collaborative planning and participatory management are essential for safeguarding both economic and environmental interests and ensuring the safety of vulnerable populations in outdoor spaces.

**Keywords:** climate justice; ecosystem services; resilient planning and management; sustainability; urban tree appraisal



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## 1. Introduction

People have a key role in shaping, forming, and preserving green areas, since inadequate maintenance and design can lead to the deterioration of the plants represented in the green infrastructure [1]. Plant species as a major element contribute individual and collective aesthetic qualitative value, with trees being not merely decorative elements but essential components of urban ecosystems. Their functions extend beyond aesthetics to encompass various ecological, environmental, and socio-economic services [2,3].

The concept of green infrastructure involves the use of multidisciplinary and interdisciplinary methodologies, including biological, agricultural, social, and other branches of science, to provide a better approach to planning and managing green areas [4]. Green infrastructure emphasizes the quality and quantity of urban and suburban green spaces, promoting biodiversity enrichment and conservation since urban greenery is comprised of different annual, bi-annual, and perennial species, including flowering species, evergreen, and deciduous trees and shrubs. Environmentally aware citizens see this natural capital as the one not inherited from the ancestors, but borrowed from future generations. However, this capital's valorization often ends with marks for vitality and ornamental value (decorativeness), including marks for the presence of phytopathological, entomological, and mechanical damage [5–8]. Users' scorings and appreciation for trees and greenery can vary based on individual preferences, cultural backgrounds, current residence, and specific needs. Urban planners, environmental advocates, and policymakers need to recognize and consider these values when making decisions about urban development and green space preservation, respecting the basic principles of climate justice [9]. Broadly considered, people value trees and greenery in their surroundings for various reasons, and these values can be both intrinsic and instrumental [10]. Exposure to green areas and trees improves mental health and facilitates children's learning and cognitive abilities, as well as focus and attention [11,12].

In the scientific realm of ecosystem services, monetary valuation methods have garnered greater attention compared to alternative valuation approaches [13,14], but such exclusive emphasis on monetary evaluation places a spotlight on instrumental values, potentially overlooking the intrinsic and relational values associated with ecosystem services [15]. Landscape tree appraisal, also referred to as tree evaluation or tree monetization, is a systematic process employed to assess the monetary value of trees within a specific landscape or urban setting. This form of appraisal holds significance for diverse applications, including property assessment, insurance claims, litigation, and establishing compensation for instances involving tree removal or damage [16]. However, this value is far from being only monetary, as it includes several factors taken into account when appraising the value of a tree (tree species, its size, health, condition, location, and the ecosystem services it provides—shade, air purification, aesthetics).

Tree appraisal is a valuable tool in urban and suburban planning, which provides local governments, professionals, and researchers with an effective tool to determine the monetary value of both public and private urban trees or can be an instrument in resolving disputes and making fair compensations [17]. Urban environments are rapidly expanding worldwide, with more than half of the global population residing in cities and urban areas [18]. This ongoing urbanization presents a unique set of challenges, including increased demands for sustainable, livable, and environmentally friendly urban spaces. In this context, the role of trees in the urban core has gained significant attention due to their multifaceted contributions to the well-being of cities and their residents. Facing limited resources and competing urban development interests, efficient tree appraisal is essential for informed decision-making and the sustainable management of urban forests [19]. The existence of the value possessed by a good and service (including natural and environmental resources) will, in turn, direct the decision-making behavior performed by individuals, communities, or organizations [20].

With the challenging urbanization and climate change era, policy and decision-makers are striving towards the implementation of nature-based solutions (NBSs) and alignment with sustainable development goals to mitigate the devastating influence that urban development has caused. Both the theory and practice teach us that blue and green infrastructures, like bioretention gardens, green walls, and green roofs, can mitigate but cannot significantly reduce the detrimental effects of meteorological events like heavy rain, storms, hail, and heat waves. The primary concern that has arisen is that urban green infrastructure might become prone to natural hazards [21]. Although devastating winds and tornadoes are not associated with European land, their emergence in the last decade has been prominent [22].

Similarly, the novelty in the last decade on the territory of Serbia is supercell storms, which first occurred in June 2013 as a consequence of a heat wave that struck Europe [23]. At the end of the period characterized by extremely high temperatures, the development of a storm along with supercell high precipitation convection took place in Serbia, producing tennis ball-sized hailstones and wind with speeds exceeding 35 m/s. Similarly, in 2023, two consecutive supercell storms hit Northern Serbia on July 19th and 21st. At first glance, understandably, the government and public focused their attention on human and material losses related to infrastructure, buildings, and personal assets, such as houses and cars, scarcely mentioning the number of fallen trees (around 3000 on the urban area of Novi

Sad). Such an approach can neglect the true extent of the events' impact; thus, a damage appraisal included in the greenery cadaster is of the utmost importance [24].

Generally, urban green infrastructure planning in Serbia, as a developing country, is often neglected and taken for granted, while potential risks are overlooked. In a previous study regarding vulnerable populations, poisonous and allergenic plant species were identified in eight primary schools and six preschools located in Novi Sad, Serbia, and a total of 22 poisonous plant species and 21 allergenic plant species were identified [25]. Contemporary studies on environmental justice are focused on agricultural losses as drought or flooding consequences [26], air pollution due to wildfires [27], and green space quality [28], but there are no investigations dealing with the climate justice impaired by climate change resulting in extreme weather events, such as supercell storms. Implementing appropriate urban greenery to mitigate climate and other societal challenges is an essential element in sustainable cities.

Due to the urban green infrastructure values stated above, inappropriate greenery choice as well as the lack of information regarding the causes of and greenery losses after supercell storm events, this paper aims to (i) assess the monetary loss according to the tree appraisal method in public green spaces of Futog (Serbia) affected by the supercell storm; (ii) estimate the trees' characteristics that influence wind-caused damage, especially canopy-driven uprooting risks; (iii) address the species-specific responses to wind-caused damage; and (iv) propose measures and highlight recommendations for the prevention of similar damage when faced with windstorms and trees' uprooting, advocating for mutual action towards green infrastructure resilient planning aligned with climate justice principles.

## 2. Materials and Methods

### *2.1. Location and Site Conditions of the Study Area*

To investigate tree valuation, this study examined 3 different case study areas belonging to the public category of fully open (park) and areas with a specific usage (schoolyards), presented in the Figure 1. These three areas included: Desanka Maksimović Elementary School (with an area of 17,547 $m^2$), the Agricultural School with the Student Dormitory (with an area of 22,907 $m^2$), and the Futog park (with an area of 4135 $m^2$). The researched greenery belongs to public spaces, whose users predominantly consist of the most vulnerable part of the population—children aged 3–18 years and the elderly. Besides them, users include educators and teachers, as well as other Futog residents who use them daily for recreation.

Futog is a suburban settlement of the City of Novi Sad, Serbia, the capital of Vojvodina. It is situated approximately 7 km (4.3 miles) northwest of the city of Novi Sad, on the left bank of the Danube River, making it part of the Danube's riverine landscape. Being a settlement on the Danube riverbank, Futog is characterized as a floodplain area of the Danube as well as a high water table terrain. The town has educational institutions, including primary schools, as well as an Agricultural High School (in the building of an old Chotek Castle) to serve the educational needs of its mainly agricultural-oriented population [29].

### *2.2. Dendrometrical Characterization*

In April and May of 2023 for the greenery cadaster establishment, the dendrometrical analysis, including both quantitative (total height and height to the first branches, trunk circumference at 1.3 m height, and crown width) and qualitative (rotten trunk and branches, phytopathological and entomological damage, vitality, and decorative value) parameters, was conducted according to Mattheck et al. [30] and Kostić et al. [31]. Marks for rotten trunk and branches and phytopathological and entomological damage vary from 1 to 3, labeled with an appropriate number of asterisks (*). Scores for vitality and decorativeness were provided by panelists—professors, research assistants, and students, according to the five-point Likert scale (1—very low, 2—low, 3—medium, 4—high, and 5—very high). The simple dendrometrical analysis was interrupted by an unexpected supercell storm development that heavily struck the entire town of Futog (on 19 July), shifting the research toward the estimation of trees' monetary value and economic losses caused by a single, devastating, less than 20 min storm. Two days later, another storm roared across this territory, augmenting the devastating effect of the former.


**Figure 1.** Town location in the broader area (marked with the red circle) and the position of three investigated public green spaces in Futog: 1—Desanka Maksimović Elementary School, 2—the Agricultural School with the student dormitory, and 3—the Futog town park.

### *2.3. Overview of the Synoptic Situation Preceding the Supercell Occurrence*

At the beginning of the second decade of July, after very hot days, there was a destabilization of the air mass in the northern regions, as a result of the development of a cyclone to the north and northwest, while simultaneously, warm air advection from the south of the continent continued. The collision zone of these two air masses resulted in the development of a strong and supercell storm that moved from west to east during the day, from the Alps across the Pannonian Plain, Slavonia, and Vojvodina to the Carpathians and the Black Sea. In the northern part of the country, localized severe weather with abundant precipitation, large hailstones, and strong winds from the northwest towards central Banat was recorded. Afterward, a surface anticyclone and warm air mass in a broad ridge over the central Mediterranean led to very warm weather. At the end of the second decade, after the development and movement of a cyclone from the northwest from the British Isles and the North Sea towards southeast and central Europe, moisture inflowed into the Alpine and Pannonian regions and another passage of a cold front occurred over Srem, Mačva, and southern Bačka towards the east, followed with the formation of a storm front predominantly in zonal high-altitude flow. Consequently, rain and heavy downpours with hurricane-strength wind gusts occurred. In other regions, in central and eastern areas, there were localized downpours with thunderstorms, which were more pronounced in southwestern Serbia, where hail accompanied the storms [32].

*2.4. Landscape Tree Appraisal*

Although monetary appraisals are more widely accepted within the private sector [33], aiming to stress capital losses, we used this type of calculation to stress the degree of damage caused by a storm and spotlight prevention measures. Unfortunately, it is not uncommon that tree appraisal is conducted after the greenery has been damaged or removed, even for private sector purposes [34], although this tool could be much more efficient as an important warning prior to the detrimental factor occurrence. Comparing five different appraisal methods, Ponce-Donoso et al. [17] concluded that the Council of Tree and Landscape Appraisers of the United States (CTLA) formula shows comparatively the best performance, considering both the statistics used and compliance with the established boundary conditions. Thus, to turn the landscape tree value into monetary value, the widely accepted and long-known CTLA calculation was applied to each of the investigated specimens (trees' size with the pronounced role of cross-sectional area, species dependence, specimens' condition, and location).

The first step was the calculation of the tree's base value by interviews and price catalogs from three local and nationally oriented nurseries, surveyed to obtain the most reliable base price, as well as one long-established and appreciated European nursery (for comparison purposes). As noted by Hegedüs et al. [35], determining the base value is very important, since even the national and local market prices may vary by 200–300% among ornamental trees with the same size and other properties. In the second step, the base value was multiplied by the cross-section area for each given tree, as well as known coefficients for species, condition, and location class [36]. The obtained monetary values expressed in national and European prices were further multiplied by the number of uprooted trees per species to calculate the total economic loses per each species.

*2.5. Statistical Analysis*

Collected data and subsequent calculations of metrical characteristics (areas and ratios derived from tree height, trunk height, and crown height and width) were subjected to a correlation analysis using the STATISTICA 14 software (Tibco, Palo Alto, CA, USA), with a confidence level of 95%. To better understand the trees' responses to detrimental wind influence, a correlation analysis between the dendrometrical measured and calculated values, on the one hand, and the percentage of uprooted trees per species in a given locality, on the other hand, was conducted.

## 3. Results

*3.1. Dendrometrical Analysis According to the Location*

3.1.1. Desanka Maksimović Elementary School

In the green area of 'Desanka Maksimović' Elementary School, there were 19 woody species with a total of 214 individuals. Based on the analysis, species from the following genera were mostly represented: *Acer*, *Tilia*, *Fraxinus*, *Corylus*, *Thuja*, and *Pinus* (Table 1). Dendrometrical analyses showed that both deciduous and coniferous species were mainly in satisfactory condition, with high ratings of vitality and decorativeness. No damage caused by various diseases and pests was observed; however, mechanical damage was not absent. Mechanical damage, such as branch breakage, cutting, and bark incision, was noted in the following species: *Fraxinus excelsior* L., *Platanus occidentalis* L., *Picea pungens* Engelm., *Thuja orientalis* L., *Thuja occidentalis* L., and *Chamaecyparis lawsoniana* L. Other coniferous species were in excellent health, possessing high ratings of decorativeness and vitality. The basic morphometrical characteristics used in the subsequent calculations are presented in Table 1.

The species *Abies nordmanniana* (Stev.) Spach., *Acer platanoides* L., *Acer pseudoplatanus* L., *Acer campestre* L., *Acer sacharinum* L., *Betula alba* L., *Corylus colurna* L., *Juniperus communis* L., *Pinus nigra* Arn., *Prunus cerasifera* Ehrh. var. 'Pissardii', and *Tilia tomentosa* Munch. have excellently adapted to the site conditions, as noted on adult multidecade-old specimens in the spring of 2023. They received the highest ratings for vitality and decorativeness, achieved from 10 to around 20 m in height and from 0.3 up to 1.2 m of trunk diameter, thereby demonstrating a high adaptability. The mentioned species are planted in close proximity, forming a cohesive unit within the schoolyard. However, the high conditional ratings and growth parameters did not imply resistance to uprooting, since some of these were the same species whose specimens were damaged the most during the storm (Table 2).

The adult mature trees of *C. colurna* and *A. sacharinum* with an excellent condition class, followed by *Fraxinus americana* L. and *F. excelsior* with a slightly lower condition class, were completely destroyed, with a total national appraised value of EUR 37,407; 7545; 5693; and 4286 as well as a European appraised value of EUR 188,195; 49,716; 26,576; and 15,948, respectively. On the contrary, species with very low vitality and decorativeness, thus in poor or extremely poor condition, such as *C. lawsoniana*, *T. occidentalis*, and *P. pungens*, contributed to the appraised economic loss with only EUR 7.96, 2965, and 2724 (from the national perspective) and EUR 25.4, 6390, and 10,800 from the European perspective, respectively. Young, most recently planted individuals of the genus *Thuja* (146 individuals), undamaged during the storm (141 individuals), increased the total percentage of unaffected greenery, concomitantly decreasing the deteriorated ones (only 9%). When these young trees were excluded from the calculations, 23.5% (16 out of 68 mature trees) of the greenery was uprooted and irreversibly lost. When considered in relation to the schoolyard area (17,547 $m^2$), the calculated loss per $m^2$ of the investigated area amounts to EUR 3.49 and 17.2 in the national and international prices, respectively.

#### 3.1.2. Agricultural High School

The second analyzed institutional green area comprised a lower number of trees but with a higher species diversity, including 26 species and 155 specimens. Based on the dendrometrical analysis, the excellent adaptability of species such as *Aesculus hippocastanum* L., *T. tomentosa*, *B. alba*, *Robinia pseudoacacia* L. var. 'Globosa', *Morus nigra* L. var. 'Pendula', *Gleditsia triacanthos* L., *Ginkgo biloba* L., and *Juglans nigra* L. can be noted. The high ratings for decorativeness and vitality, among other growth and developmental metrical indicators (Table 3), confirm the outstanding adaptability of these species. The trees of *A. hippocastanum*, *Cedrus atlantica* (Endl.) Manetti ex Carrière, *Cornus mas* L., *Ginkgo biloba* L., *Morusnigra* L., *P. pungens*, *P. nigra*, *Pinus strobus* L., *Quercus robur* L., *P. occidentalis*, *R. pseudoacacia* 'Globosa', and *T. tomentosa*, mostly planted in groups, received the highest ratings for vitality and decorativeness (scores of 4–5). Again, higher values of growth parameters (tree size from 16.6 to 25.0 m, canopy diameters from 4.0 m to 22.0 m, and trunk diameter from 0.45 to 1 m) did not influence the better resistance to the wind strike (Table 4).

The adult mature trees of *A. hippocastanum*, *C. mas*, *Picea omorika* (Pančić) Purk., *P. nigra* (Figure 2), and *Q. robur*, with excellent decorativeness and vitality (scores of 5 or 4.5) thus with a condition class values of 100% and 90%, followed by *B. alba*, *G. triacanthos*, *P. occidentalis*, *Sophora japonica* L., and *T. tomentosa* with a slightly lower decorativeness and vitality score (4) and condition class (80%), were completely destroyed, with a total appraised value of EUR 15,455; 4676; 15,360; 88,907; 27,992; 2410.4; 1221; 95,946; 12,348; and 25,764 (from the national perspective) and EUR 102,288; 42,718; 53,458; 232,365; 186,613; 7845; 15,533; 277,631; 40,270, and 54,554 (from the European perspective), respectively. On the contrary, species with a very low vitality and decorativeness, thus in relatively poor or extremely poor condition, such as *A. negundo* and *C. lawsoniana*, contributed to the national appraised economic loss, with only EUR 857.4 and 372.9, respectively. Expressed in the European prices, those values achieved EUR 4711 and 2509.6, respectively. The total loss per green area was very high (albeit 30% of trees and EUR 291,310,for the national, and EUR 742,865 for the international prices) owing to the uprooting of healthy and valuable specimens. Interestingly, species of a very poor condition and undesirable appearance, *Celtis occidentalis* L., *R. pseudo accacia*, *T. occidentalis*, and *Ulmus pumila* L., all being labeled as invasive or potentially invasive in Serbia and surrounding countries, were not affected by the storm despite their state (Table 4). When calculated in relation to the investigated schoolyard area (22,907 $m^2$), the calculated loss per $m^2$ of the area amounts to EUR 12.7 and 32.4 in the national and international prices, respectively.

**Table 1.** Dendrometrical analysis of the greenery belonging to the 'Desanka Maksimović' elementary school as valorized in the spring of 2023.

| Species and the Number of Trees Belonging to the Given Species | Average Total Height (m) | Average Trunk Height (m) | Average Trunk Diameter at the Breast Height (cm) | Average Canopy Diameter (m) | Average Rotten Trunk or Branch Occurrence | Average Mechanical Damage Intensity | Average Phytopathological and Entomological Damage | Average Vitality Scores | Average Ornamental Value |
|---|---|---|---|---|---|---|---|---|---|
| *Abies nordmanniana* (1) | 25.4 | 7.2 | 1.5 | 12.2 | - | - | - | 5.0 | 5.0 |
| *Acer campestre* (2) | 15.8 | 4.8 | 0.5 | 7.5 | - | - | - | 5.0 | 5.0 |
| *Acer platanoides* (5) | 16.4 | 5.0 | 0.5 | 7.3 | - | * | - | 4.0 | 4.0 |
| *Acer pseudoplatanus* (5) | 14.0 | 4.3 | 0.5 | 6.0 | - | - | - | 5.0 | 5.0 |
| *Acer saccharinum*(7) | 16.5 | 5.0 | 0.4 | 8.0 | - | - | - | 5.0 | 5.0 |
| *Betula alba* (2) | 17.8 | 5.4 | 0.3 | 5.8 | - | - | - | 5.0 | 5.0 |
| *Chamaecyparis lawsoniana* (1) | 5.0 | 0.3 | 0.2 | 2.6 | - | *** | - | 1.0 | 1.0 |
| *Corylus colurna* (12) | 23.2 | 8.7 | 0.7 | 5.0 | - | - | - | 5.0 | 5.0 |
| *Fraxinus americana* (5) | 14.0 | 3.8 | 0.5 | 4.9 | - | ** | - | 4.0 | 3.0 |
| *Fraxinus excelsior* (2) | 13.2 | 4.2 | 0.5 | 4.4 | - | * | - | 4.0 | 4.0 |
| *Juniperus communis* (4) | 3.4 | 0.4 | 0.3 | 0.9 | - | - | - | 5.0 | 5.0 |
| *Picea omorika* (3) | 5.4 | 0.4 | 0.3 | 3.3 | - | - | - | 5.0 | 5.0 |
| *Picea pungens* (2) | 3.2 | 0.6 | 0.3 | 3.5 | - | ** | - | 3.0 | 3.0 |
| *Pinus nigra* (10) | 12.2 | 3.5 | 0.2 | 6.0 | - | - | - | 5.0 | 5.0 |
| *Platanus occidentalis* (2) | 18.5 | 4.2 | 1.3 | 15.3 | * | * | - | 2.0 | 2.0 |
| *Prunus cerasifera* 'Pissardii' (1) | 11.0 | 3.5 | 0.3 | 3.6 | - | - | - | 5.0 | 5.0 |
| *Thuja occidentalis* (76) | 3.5 | 0.3 | 0.2 | 1.7 | - | *** | - | 3.0 | 2.0 |
| *Thuja orientalis* (70) | 5.6 | 0.5 | 0.2 | 2.6 | - | *** | - | 3.0 | 2.0 |
| *Tilia tomentosa* (6) | 20.2 | 5.3 | 0.65 | 6.7 | - | - | - | 5.0 | 5.0 |

Note: The number of asterisks represents the intensity of the recorded damage (*—low, **—medium, ***—high), while vitality and ornamental value scores are presented on a 5-point Likert scale, ranging from 1 (very low) to 5 (very high).

**Table 2.** Tree appraisal after the storm event in July 2023 at the 'Desanka Maksimović' elementary school.

| Species and the Number of Trees Belonging to the Given Species | Number of Completely Damaged Trees during the Supercell Storm Event | Average Base Value per cm² (Local Nursery) | Average Base Value per cm² (European Nursery) | Average Cross-Section Area (cm²) | CTLA Species Class | CTLA Condition Class | CTLA Location Class | Monetary Value per Specimen (Local Value, EUR) | Monetary Value per Specimen (European Value, EUR) | Total Economic Loss per Species (Local Value, EUR) | Total Economic Loss per Species (European Value, EUR) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Abies nordmanniana* (1) | 0 | 7.77 | 18.1 | 7854.5 | 1.0 | 1.0 | 0.75 | 45,772 | 106,624 | / | / |
| *Acer campestre* (2) | 0 | 2.07 | 18.3 | 1963.5 | 1.0 | 1.0 | 0.75 | 3048 | 26,946 | / | / |
| *Acer platanoides* (5) | 0 | 2.66 | 14.8 | 1590.4 | 1.0 | 0.8 | 0.75 | 2538 | 14,121 | / | / |
| *Acer pseudoplatanus*(5) | 0 | 2.52 | 14.6 | 1963.5 | 0.6 | 1.0 | 0.75 | 2227 | 12,902 | / | / |
| *Acer saccharinum* (7) | 3 | 3.79 | 14.1 | 1256.6 | 0.4 | 1.0 | 0.75 | 1429 | 5316 | 4286 | 15,948 |
| *Betula alba* (2) | 0 | 4.21 | 13.7 | 490.9 | 0.2 | 1.0 | 0.75 | 310.0 | 1009 | / | / |
| *Chamaecyparis lawsoniana* (1) | 1 | 2.11 | 6.73 | 314.2 | 0.8 | 0.2 | 0.75 | 7.96 | 25.4 | 7.96 | 25.4 |
| *Corylus colurna* (12) | 4 | 3.24 | 16.3 | 3848.5 | 1.0 | 1.0 | 0.75 | 9352 | 47,049 | 37,407 | 188,195 |
| *Fraxinus americana* (5) | 3 | 3.02 | 19.9 | 1734.9 | 0.8 | 0.8 | 0.75 | 2515 | 16,572 | 7545 | 49,716 |
| *Fraxinus excelsior* (2) | 2 | 3.02 | 14.1 | 1963.5 | 0.8 | 0.8 | 0.75 | 2846 | 13,288 | 5693 | 26,576 |
| *Juniperus communis* (4) | 0 | 4.60 | 25.0 | 660.5 | 0.6 | 1.0 | 0.75 | 1367 | 7429 | / | / |
| *Picea omorika* (3) | 0 | 4.31 | 15.0 | 855.3 | 1.0 | 1.0 | 0.75 | 2765 | 9623 | / | / |
| *Picea pungens* (2) | 2 | 4.01 | 15.9 | 754.8 | 1.0 | 0.6 | 0.75 | 1362 | 5400 | 2724 | 10,800 |
| *Pinus nigra* (10) | 0 | 6.16 | 16.1 | 490,9 | 0.6 | 1.0 | 0.75 | 1361 | 3557 | / | / |
| *Platanus occidentalis* (2) | 0 | 4.70 | 13.6 | 11,309 | 0.8 | 0.4 | 0.75 | 12,757 | 36,914 | / | / |
| *Prunus cerasifera* 'Pisardii' (1) | 1 | 2.70 | 18.2 | 706.9 | 0.4 | 1.0 | 0.75 | 572.6 | 3860 | 572.6 | 3860 |
| *Thuja occidentalis* (76) | 5 | 8.63 | 18.6 | 254.5 | 0.6 | 0.6 | 0.75 | 593.0 | 1278 | 2965 | 6390 |
| *Thuja orientalis* (70) | 0 | 4.53 | 17.6 | 314.2 | 0.6 | 0.6 | 0.75 | 384.3 | 1493 | / | / |
| *Tilia tomentosa* (7) | 0 | 6.47 | 13.7 | 3318.3 | 1.0 | 1.0 | 0.75 | 16,102 | 34,095 | / | / |
| Total loss | 21 | | | | | | | | | 61,200 | 301,510 |
| The average loss per fallen tree in EUR | | | | | | | | | | 2914 | 14,358 |
| EUR/m² of the investigated green area | | | | | | | | | | 3.49 | 17.2 |

**Table 3.** Dendrometrical analysis of the greenery belonging to the Agricultural High School as valorized in the spring of 2023.

| Species and the Number of Trees Belonging to the Given Species | Average Total Height (m) | Average Trunk Height (m) | Average Trunk Diameter at the Chest Height (cm) | Average Canopy Diameter (m) | Average Rotten Trunk or Branch Occurrence | Average Mechanical Damage Intensity | Average Phytopathological and Entomological Damage | Average Vitality Scores | Average Ornamental Value |
|---|---|---|---|---|---|---|---|---|---|
| *Acer negundo* (5) | 16.6 | 3.0 | 0.45 | 9.0 | - | * | - | 3.0 | 4.0 |
| *Aesculus hippocastanum* (8) | 18.5 | 3.5 | 0.65 | 9.8 | - | - | - | 5.0 | 5.0 |
| *Betula alba* (9) | 18.5 | 3.8 | 0.45 | 9.5 | - | - | - | 4.0 | 4.0 |
| *Cedrus atlantica* (2) | 13.5 | 2.8 | 0.70 | 6.0 | - | - | - | 5.0 | 5.0 |
| *Celtis occidentalis* (8) | 18.5 | 4.2 | 0.50 | 6.8 | * | ** | - | 2.0 | 2.0 |
| *Chamaecyparis lawsoniana* (11) | 5.4 | 0.3 | 0.25 | 2.3 | - | *** | - | 1.0 | 1.0 |
| *Cornus mas* (2) | 6.5 | 2.0 | 0.35 | 5.5 | - | - | - | 5.0 | 5.0 |
| *Ginkgo biloba* (1) | 5.5 | 1.0 | 0.30 | 2.5 | - | - | - | 5.0 | 5.0 |
| *Gleditsia triacanthos* (1) | 17.3 | 2.5 | 0.60 | 5.5 | * | - | - | 4.0 | 4.0 |
| *Juglans nigra* (7) | 10.5 | 1.5 | 0.30 | 7.5 | - | - | - | 4.0 | 4.0 |
| *Morus nigra* 'Pendula' (1) | 2.5 | 0.8 | 0.30 | 1.5 | - | - | - | 5.0 | 5.0 |
| *Picea abies* (13) | 13.8 | 3.5 | 0.65 | 5.9 | - | ** | - | 3.0 | 3.0 |
| *Pice aomorika* (6) | 5.6 | 1.7 | 0.55 | 4.0 | - | - | - | 5.0 | 5.0 |
| *Picea pungens* (6) | 7.8 | 1.5 | 0.35 | 3.5 | - | - | - | 5.0 | 5.0 |
| *Pinus nigra* (27) | 19.5 | 6.5 | 0.55 | 6.0 | - | * | - | 4.5 | 4.5 |
| *Pinus strobus* (2) | 18.4 | 6.0 | 0.60 | 5.5 | - | * | - | 4.5 | 4.5 |
| *Platanus occidentalis* (12) | 22 | 3.5 | 0.95 | 16.5 | - | * | - | 4.0 | 4.0 |
| *Quercus robur* (5) | 25 | 5.0 | 1.00 | 22 | - | * | - | 4.5 | 4.5 |
| *Robinia pseudoacacia* 'Globosa' (7) | 5.5 | 2.8 | 0.30 | 4.0 | - | - | - | 5.0 | 5.0 |
| *Robinia pseudoacacia* (5) | 15.5 | 2.8 | 0.50 | 7.5 | * | *** | - | 2.0 | 2.0 |
| *Sophora japonica* (4) | 17.4 | 2.9 | 0.45 | 4.0 | - | - | - | 5.0 | 5.0 |
| *Thuja occidentalis* (6) | 5.2 | 1.2 | 0.30 | 3.3 | - | *** | - | 2.0 | 1.0 |
| *Tilia tomentosa* (4) | 23.3 | 4.8 | 0.65 | 12.5 | - | - | - | 4.0 | 4.0 |
| *Ulmus pumila* (3) | 5.5 | 3.8 | 0.55 | 6.5 | * | *** | - | 2.0 | 2.0 |

Note: The number of asterisks represents the intensity of the recorded damage (*—low, **—medium, ***—high), while vitality and ornamental value scores are presented on a 5-point Likert scale, ranging from 1 (very low) to 5 (very high).

**Table 4.** Tree appraisal after the storm event in July 2023 at the Agricultural High School.

| Species and the Number of Trees Belonging to the Given Species | Number of Completely Damaged Trees during the Supercell Storm Event | Average Base Value per cm$^2$ | Average Base Value per cm$^2$ (European Nursery) | Average Cross-Section Area (cm$^2$) | CTLA Species Class | CTLA Condition Class | CTLA Location Class | Monetary Value per Specimen (EUR) | Monetary Value per Specimen (European Value, EUR) | Total Economic Loss per Species (EUR) | Total Economic Loss per Species (European Value, EUR) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Acer negundo* (5) | 3 | 2.53 | 13.9 | 1590.4 | 0.4 | 0.6 | 0.75 | 285.8 | 1570 | 857.4 | 4711 |
| *Aesculus hippocastanum* (8) | 3 | 2.07 | 13.7 | 3318.3 | 1.0 | 1.0 | 0.75 | 5151.7 | 34,096 | 15,455 | 102,288 |
| *Betula alba* (9) | 3 | 4.21 | 13.7 | 1590.4 | 0.2 | 0.8 | 0.75 | 803.5 | 2615 | 2410.4 | 7845 |
| *Cedrus atlantica* (2) | 0 | 6.92 | 14.8 | 3848.5 | 1.0 | 1.0 | 0.75 | 20,089 | 42.990 | / | / |
| *Celtis occidentalis* (8) | 0 | 2.02 | 20.2 | 1963.5 | 0.6 | 0.4 | 0.75 | 713.9 | 7139 | / | / |
| *Chamaecyparis lawsoniana* (11) | 3 | 2.11 | 6.73 | 490.9 | 0.8 | 0.2 | 0.75 | 124.3 | 836.5 | 372.9 | 2509.6 |
| *Cornus mas* (2) | 2 | 3.24 | 29.6 | 962.1 | 1.0 | 1.0 | 0.75 | 2338 | 21,360 | 4676 | 42,718 |
| *Ginkgo biloba* (1) | 0 | 10.2 | 25.1 | 706.9 | 1.0 | 1.0 | 0.75 | 5408 | 13,308 | / | / |
| *Gleditsia triacanthos* (1) | 1 | 1.80 | 22.9 | 2827.4 | 0.4 | 0.8 | 0.75 | 1221 | 15,533 | 1221 | 15,533 |
| *Juglans nigra* (7) | 0 | 2.43 | 19.6 | 706.9 | 0.8 | 0.8 | 0.75 | 824.5 | 6650 | / | / |
| *Morus nigra* 'Pendula' (1) | 0 | 2.59 | 13.4 | 706.9 | 0.2 | 1.0 | 0.75 | 274.6 | 1421 | / | / |
| *Picea abies* (13) | 0 | 7.77 | 9.51 | 3318.3 | 1.0 | 0.6 | 0.75 | 11,602 | 14,200 | / | / |
| *Picea omorika* (6) | 2 | 4.31 | 15.0 | 2375.8 | 1.0 | 1.0 | 0.75 | 7680 | 26,729 | 15,360 | 53,458 |
| *Picea pungens* (6) | 0 | 4.01 | 15.9 | 962.1 | 1.0 | 1.0 | 0.75 | 3500 | 13,878 | / | / |
| *Pinus nigra* (27) | 15 | 6.16 | 16.1 | 2375.8 | 0.6 | 0.9 | 0.75 | 5927 | 15,491 | 88,907 | 232,365 |
| *Pinus strobus* (2) | 0 | 5.18 | 15.7 | 2827.4 | 0.8 | 0.9 | 0.75 | 7910 | 23,974 | / | / |
| *Platanus occidentalis* (12) | 6 | 4.70 | 13.6 | 7088.2 | 0.8 | 0.8 | 0.75 | 15,991 | 46,272 | 95,946 | 277,631 |
| *Quercus robur* (5) | 2 | 2.64 | 17.6 | 7854 | 1.0 | 0.9 | 0.75 | 13,996 | 93,307 | 27,992 | 186,613 |
| *Robinia pseud acacia* 'Globosa' (7) | 0 | 2.58 | 15.8 | 706.9 | 0.2 | 1.0 | 0.75 | 273.6 | 1676 | / | / |
| *Robinia pseudoacacia* (5) | 0 | 3.59 | 15.8 | 1963.5 | 0.2 | 0.2 | 0.75 | 211.5 | 931 | / | / |
| *Sophora japonica* (4) | 2 | 6.47 | 21.1 | 1590.4 | 0.8 | 1.0 | 0.75 | 6174 | 20,135 | 12,348 | 40,270 |
| *Thuja occidentalis* (6) | 0 | 8.63 | 18.6 | 706.9 | 0.6 | 0.4 | 0.75 | 1098 | 2366 | / | / |
| *Tilia tomentosa* (4) | 2 | 6.47 | 13.7 | 3318.3 | 1.0 | 0.8 | 0.75 | 12,882 | 27,277 | 25,764 | 54,554 |
| *Ulmus pumila* (3) | 0 | 1.28 | 13.1 | 2375.8 | 0.2 | 0.4 | 0.75 | 182.5 | 1868 | / | / |
| Total loss | 44 | | | | | | | | | 291,310 | 742,865 |
| The average loss per fallen tree in EUR | | | | | | | | | | 6621 | 16,883 |
| EUR/m$^2$ of the investigated green area | | | | | | | | | | 12.72 | 32.44 |

(**a**) (**b**)

**Figure 2.** (**a**) *Pinus nigra* specimens planted in a group photographed in the spring of 2023 and (**b**) uprooted *P. nigra* trees after a storm in July of 2023.

### 3.1.3. Town Park

The third analyzed area, the town park, consists of 14 species, represented by 66 specimens (Table 5). White ash (*F. excelsior*) was the most prevalent in the analyzed area of the park with a total number of 23 trees, which enclose the green area, predominantly from the southern side. While gathering data for cadaster purposes, the species was in excellent health, and its decorative features were evident throughout the year, both at the beginning of the vegetation period and in winter, when fruits linger on the branches. Following the white ash, in terms of presence in the park and overall appearance, were nine trees of the silver birch (*B. alba*) group planted as a triangle, with three specimens in each of the three groups. In the spring and early summer, the trees were in satisfactory health and vitality. Frankly, all present specimens in the park were labeled with high scores for decorativeness and vitality (no less than 4) and were robustly developed, with the majority of trees reaching 10 to 20 m or even up to 22.5 m (*Abies alba* Mill.). With scores of 4.5 and 4 for decorativeness and vitality, respectively, *P. nigra* and *T. tomentosa* had 5 trees per species, while the remaining species consisted of 1–4 specimens.

With more than 50% of uprooted trees, this green area was mostly affected by the storm event. Mature, mainly deciduous trees of *A. hippocastanum*, *B. alba*, *Catalpa bignonioides* Walt., *F. excelsior*, and *P. cerasifera* 'Pissardii', with excellent decorativeness and vitality (scores of 5), thus a condition class of 100%, followed by *A. saccharinum*, *J. nigra*, *P. nigra* (as only fallen conifer species), and *T. tomentosa* with slightly lesser decorativeness and vitality scores (4.5 and 4.0) and a condition class values of 90% and 80%, were completely destroyed with a total appraised value of EUR 3688; 4764; 1242; 38,745; 6234; 3429; 733; 29,636; and 54,880 (from the national perspective), as well as 24,408; 15,503; 8948; 180,896; 42,022; 12,756; 5912; 77,455; and 116,206 (from the European perspective), respectively. Surprisingly, coniferous trees belonging to *A. alba*, *P. abies*, *P. omorika*, and *P. menziesii* were not affected by the storm in this green area. The total loss per given green area was very high (more than 50% of trees with EUR 143,351 from the national and EUR 484,106 from the international perspective), owing to the uprooting of healthy and valuable broadleaf individuals reaching from 10.0 to 21.3 m in height and from 3.6 to 16.5 m in width (Table 6). When expressed in relation to the park area (4135 $m^2$), the calculated loss per $m^2$ of the investigated area amounts to EUR 34.7 and 117 in the national and international prices, respectively.

**Table 5.** Dendrometrical analysis of the greenery belonging to the town park as valorized in the spring of 2023.

| Species and the Number of Trees Belonging to the Given Species | Average Total Height (m) | Average Trunk Height (m) | Average Trunk Diameter at the Chest Height (cm) | Average Canopy Diameter (m) | Average Rotten Trunk or Branches Occurrence (%) | Average Mechanical Damage Intensity | Average Phyto-pathological and Entomological Damage (%) | Average Vitality Scores | Average Ornamental Value |
|---|---|---|---|---|---|---|---|---|---|
| *Abies alba* (1) | 22.4 | 3.8 | 0.80 | 5.7 | - | - | - | 5.0 | 5.0 |
| *Acer saccharinum* (3) | 14.6 | 3.0 | 0.40 | 9.0 | - | - | - | 4.0 | 4.0 |
| *Aesculus hippocastanum* (1) | 18.5 | 3.5 | 0.55 | 9.8 | - | - | - | 5.0 | 5.0 |
| *Betula alba* (9) | 19.5 | 4.2 | 0.40 | 6.5 | - | - | - | 5.0 | 5.0 |
| *Catalpa bignonioides* (2) | 12.0 | 1.5 | 0.50 | 5.4 | - | - | - | 5.0 | 5.0 |
| *Fraxinus excelsior* (23) | 12.6 | 1.9 | 0.55 | 4.0 | - | - | - | 5.0 | 5.0 |
| *Juglans nigra* (2) | 10.0 | 1.5 | 0.20 | 7.0 | - | - | - | 4.0 | 4.0 |
| *Picea abies* (4) | 13.0 | 3.5 | 0.60 | 5.9 | - | ** | - | 4.0 | 4.0 |
| *Picea omorika* (3) | 6.6 | 1.9 | 0.50 | 4.0 | - | - | - | 5.0 | 5.0 |
| *Pinus nigra* (5) | 20.5 | 6.0 | 0.55 | 6.0 | - | - | - | 4.5 | 4.5 |
| *Platanus occidentalis* (1) | 21.0 | 3.5 | 1.80 | 16.5 | - | * | - | 4.5 | 4.5 |
| *Prunus cerasifera* 'Pisardii' (3) | 10.0 | 1.2 | 0.70 | 3.6 | - | - | - | 5.0 | 5.0 |
| *Pseudotsuga menziesii* (4) | 27.0 | 4.5 | 0.55 | 6.0 | - | - | - | 5.0 | 5.0 |
| *Tilia tomentosa* (5) | 21.3 | 4.8 | 0.60 | 7.4 | - | - | - | 4.0 | 4.0 |

Note: The number of asterisks represents the intensity of the recorded damage (*—low, **—medium), while vitality and ornamental value scores are presented on a 5-point Likert scale, ranging from 1 (very low) to 5 (very high).

**Table 6.** Tree appraisal after the storm event in July of 2023 at the town park.

| Species and the Number of Trees Belonging to the Given Species | Number of Completely Damaged Trees during the Supercell Storm Event | Average Base Value per cm$^2$ | Average Base Value per cm$^2$ (European Nursery) | Average Cross-Section Area (cm$^2$) | CTLA Species Class | CTLA Condition Class | CTLA Location Class | Monetary Value per Specimen (EUR) | Monetary Value per Specimen (European Value, EUR) | Total Economic Loss per Species (EUR) | Total Economic Loss per Species (European Value, EUR) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Abies alba* (1) | 0 | 11.5 | 18.5 | 5026.6 | 1.0 | 1.0 | 0.75 | 43,354 | 69,743 | / | / |
| *Acer saccharinum* (3) | 3 | 3.79 | 14.1 | 1256.6 | 0.4 | 0.8 | 0.75 | 1143 | 4252 | 3429 | 12,756 |
| *Aesculus hippocastanum* (1) | 1 | 2.07 | 13.7 | 2375.8 | 1.0 | 1.0 | 0.75 | 3688 | 24,408 | 3688 | 24,408 |
| *Betula alba* (9) | 6 | 4.21 | 13.7 | 1256.6 | 0.2 | 1.0 | 0.75 | 794 | 2584 | 4764 | 15,503 |
| *Catalpa bignonioides*(2) | 2 | 2.11 | 15.2 | 1963.5 | 0.2 | 1.0 | 0.75 | 621 | 4474 | 1242 | 8948 |
| *Fraxinus excelsior* (23) | 9 | 3.02 | 14.1 | 2375.8 | 0.8 | 1.0 | 0.75 | 4305 | 20,100 | 38,745 | 180,896 |
| *Juglans nigra* (2) | 2 | 2.43 | 19.6 | 314.2 | 0.8 | 0.8 | 0.75 | 366.5 | 2956 | 733 | 5912 |
| *Picea abies* (4) | 0 | 7.77 | 9.51 | 2827.4 | 1.0 | 0.8 | 0.75 | 13,181 | 16,133 | / | / |
| *Picea omorika* (3) | 0 | 4.31 | 15.0 | 1963.5 | 1.0 | 1.0 | 0.75 | 6347 | 22,089 | / | / |
| *Pinus nigra* (5) | 5 | 6.16 | 16.1 | 2375.8 | 0.6 | 0.9 | 0.75 | 5927 | 15,491 | 29,636 | 77,455 |
| *Platanus occidentalis* (1) | 0 | 4.70 | 13.6 | 21,382 | 0.8 | 0.9 | 0.75 | 54,268 | 157,031 | / | / |
| *P. cerasifera* 'Pisardii' (3) | 2 | 2.70 | 18.2 | 3848.5 | 0.4 | 1.0 | 0.75 | 3117 | 21,011 | 6234 | 42,022 |
| *Pseudotsuga menziesii* (4) | 0 | 4.31 | 29.1 | 2375.8 | 1.0 | 1.0 | 0.75 | 7680 | 51,853 | / | / |
| *Tilia tomentosa* (5) | 5 | 6.47 | 13.7 | 2827.4 | 1.0 | 0.8 | 0.75 | 10,976 | 23,241 | 54,880 | 116,206 |
| Total loss | 34 | | | | | | | | | 143,351 | 484,106 |
| The average loss per fallen tree in EUR | | | | | | | | | | 4216 | 14,238 |
| EUR/m$^2$ of the investigated green area | | | | | | | | | | 34.7 | 117 |

### 3.2. Correlation Analysis

The correlation analyses were performed to assess the relationship between tree properties and potential risk from storm uprooting. All metrical values expressed significant correlations with tree height, except the canopy area to trunk area ratio and percentage of uprooted trees (Table 7). Related to the percentage of uprooted trees as the most important wind damage indicator, there was a general absence of connection between this parameter and whole-tree architecture expressed through the tree height, trunk height, canopy height and diameter as well as the obtained calculations when observed solely. Only when the canopy area (CA—calculated from canopy height and width) was divided by the barren trunk area (TrA—calculated from trunk height and diameter at the breast height), a significant correlation with uprooting was obtained (r = 0.38).

**Table 7.** Correlation analysis of tree, trunk, and canopy dendrometrical values and uprooting percentages.

| | TH | TrH | CD | CH | CA | CA/TrH | CA/TH | DBH/TH | CA/TrA | UT |
|---|---|---|---|---|---|---|---|---|---|---|
| TH * | 1.00 | 0.69 | 0.68 | 0.94 | 0.74 | 0.42 | 0.65 | −0.55 | −0.16 | 0.05 |
| TrH | 0.69 | 1.00 | 0.37 | 0.41 | 0.32 | −0.09 | 0.20 | −0.37 | −0.42 | −0.10 |
| CD | 0.68 | 0.37 | 1.00 | 0.69 | 0.96 | 0.78 | 0.97 | −0.16 | 0.06 | 0.04 |
| CH | 0.94 | 0.41 | 0.69 | 1.00 | 0.79 | 0.58 | 0.72 | −0.52 | −0.01 | 0.11 |
| CA | 0.74 | 0.32 | 0.96 | 0.79 | 1.00 | 0.82 | 0.97 | −0.19 | 0.08 | 0.05 |
| CA/TrH | 0.42 | −0.09 | 0.78 | 0.58 | 0.82 | 1.00 | 0.87 | −0.11 | 0.52 | 0.17 |
| CA/TH | 0.65 | 0.20 | 0.97 | 0.72 | 0.97 | 0.87 | 1.00 | −0.17 | 0.17 | 0.09 |
| DBH/TH | −0.55 | −0.37 | −0.16 | −0.52 | −0.19 | −0.11 | −0.17 | 1.00 | −0.28 | −0.21 |
| CA/TrA | −0.16 | −0.42 | 0.06 | −0.01 | 0.08 | 0.52 | 0.17 | −0.28 | 1.00 | **0.38** |
| UT | 0.05 | −0.10 | 0.04 | 0.11 | 0.05 | 0.17 | 0.09 | −0.21 | 0.38 | 1.00 |

*—Tree height (TH); trunk height (TrH); canopy diameter (CD); canopy height (CH); canopy area (CA); canopy area relative to trunk height (CA/TrH); canopy area relative to tree height (CA/TH); diameter at breast height relative to tree height (DBH/TH); canopy area relative to trunk area (CA/TrA); percentage of uprooted trees (UT). Underlined values were statistically significant according to the Pearson correlation coefficient, $p \leq 0.05$.

Aiming to understand the species influence on uprooting, a separate correlation diagram was drawn for the aforementioned variables (Figure 3). The correlation between the CA/TrA ratio and the percentage of uprooted trees was the most pronounced in *F. excelsior*, *P. omorica*, *C. colurna*, *A. hippocastanum*, *B. alba*, *Q. robur*, and *P. occidentalis* (from locality II) in the closest proximity to the correlation line. The correlation weakened as the canopy area/trunk area decreased with a concomitant uprooting percentage increase, and vice-versa when this ratio increased, followed by a decrease in uprooting.

Furthermore, although initially insignificant (r = 0.05), a correlation diagram was created for the canopy area (as a single factor) and percentage of uprooted trees to obtain an insight into the species or specimens that were closer to the correlation line (linear relationship). When the outliers with extreme values of 0% and 100% of uprooted trees were excluded from the analysis, it was possible to obtain more profound results, with a correlation coefficient increase up to 0.28 for CA and percentage of uprooted trees (Table 8). When outliers were excluded, more species were positioned in a correlation line proximity—*C. colurna*, *P. omorika*, *P. nigra*, *S. japonica*, *B. alba*, *A. hippocastanum*, *F. excelsior*, *A. saccharinum*, *T. tomentosa*, *P. occidentalis*, and *Q. robur* (Figure 4).

**Table 8.** Correlation analysis of tree, trunk, and canopy dendrometrical values and uprooting percentages with the outliers excluded.

| | TH | TrH | CD | CH | CA | CA/TrH | CA/TH | DBH/TH | CA/TrA | UT |
|---|---|---|---|---|---|---|---|---|---|---|
| TH * | 1.00 | 0.81 | 0.73 | 0.97 | 0.75 | 0.49 | 0.70 | −0.68 | −0.07 | 0.05 |
| TrH | 0.81 | 1.00 | 0.41 | 0.65 | 0.40 | 0.03 | 0.33 | −0.57 | −0.40 | 0.06 |
| CD | 0.73 | 0.41 | 1.00 | 0.78 | 0.99 | 0.86 | 0.99 | -0.29 | 0.25 | 0.17 |
| CH | 0.97 | 0.65 | 0.78 | 1.00 | 0.81 | 0.63 | 0.77 | −0.66 | 0.07 | 0.04 |
| CA | 0.75 | 0.40 | 0.99 | 0.81 | 1.00 | 0.89 | 0.99 | −0.30 | 0.29 | 0.28 |

**Table 8.** *Cont.*

| | TH | TrH | CD | CH | CA | CA/TrH | CA/TH | DBH/TH | CA/TrA | UT |
|---|---|---|---|---|---|---|---|---|---|---|
| CA/TrH | <u>0.49</u> | 0.03 | <u>0.86</u> | <u>0.63</u> | <u>0.89</u> | 1.00 | <u>0.91</u> | −0.15 | <u>0.60</u> | 0.01 |
| CA/TH | <u>0.70</u> | 0.33 | <u>0.99</u> | <u>0.77</u> | <u>0.99</u> | <u>0.91</u> | 1.00 | −0.27 | 0.31 | 0.14 |
| DBH/TH | <u>−0.68</u> | <u>−0.57</u> | −0.29 | <u>−0.66</u> | −0.30 | −0.15 | −0.27 | 1.00 | −0.16 | 0.01 |
| CA/TrA | −0.07 | −0.40 | 0.25 | 0.07 | 0.29 | <u>0.60</u> | 0.31 | −0.16 | 1.00 | −0.32 |
| UT | 0.05 | 0.06 | 0.17 | 0.04 | 0.28 | 0.01 | 0.14 | 0.01 | −0.32 | 1.00 |

*—Tree height (TH); trunk height (TrH); canopy diameter (CD); canopy height (CH); canopy area (CA); canopy area relative to trunk height (CA/TrH); canopy area relative to tree height (CA/TH); diameter at breast height relative to tree height (DBH/TH); canopy area relative to trunk area (CA/TrA); percentage of uprooted trees (UT). Underlined values were statistically significant according to the Pearson correlation coefficient, $p \leq 0.05$.

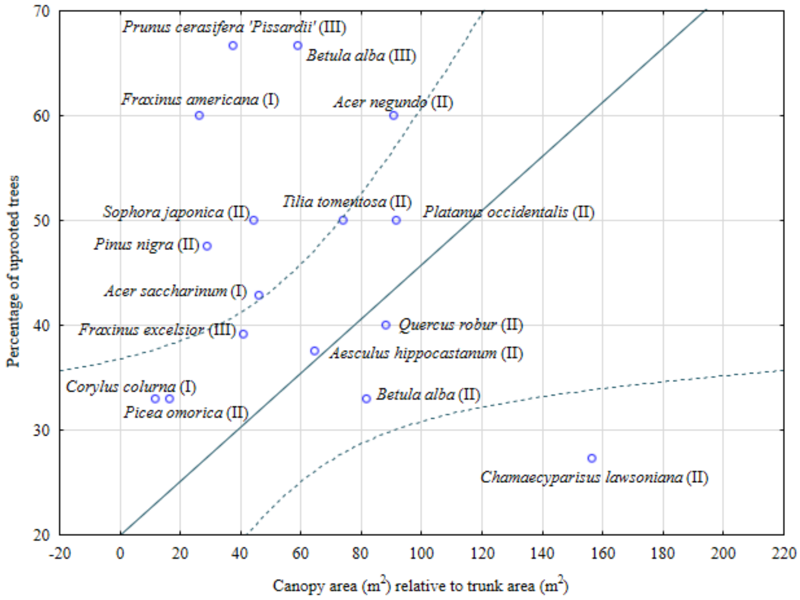


**Figure 3.** Diagram of the correlations between the percentage of uprooted trees and the ratio between the canopy area and trunk area (both in $m^2$). If a species appears in multiple locations, it is indicated in Roman letters to which location the result refers.

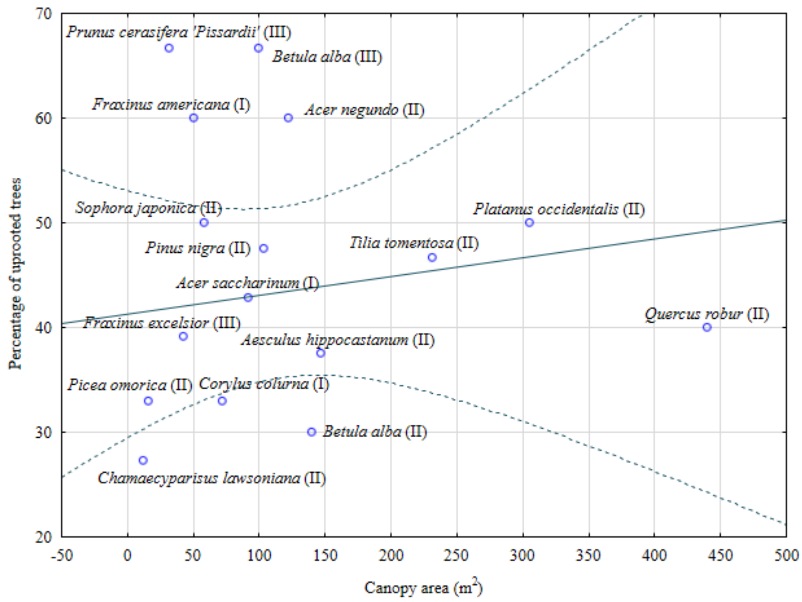


**Figure 4.** Diagram of the correlations between the percentage of uprooted trees and canopy area ($m^2$). If a species appears in multiple locations, it is indicated in Roman letters to which location the result refers.

*3.3. Dendrological Analysis According to the Species Affected*

Excluding the species that were not affected by the storm (outliers with 0% of uprooted or damaged trees), figures for the number and percentage of uprooted trees accounting for all three investigated areas were created. Seven species experienced 5 (in *T. occidentalis*) to 20 (in *P. nigra*) of completely damaged trees (Figure 5). When observed as percentages, three species experienced 100% of uprooted trees (*C. bignonioides*, *C. mas*, and *G. triacanthos*), four species experienced 60–75% of uprooted trees, while 30–50% of uprooting was noted for nine species (Figure 6).

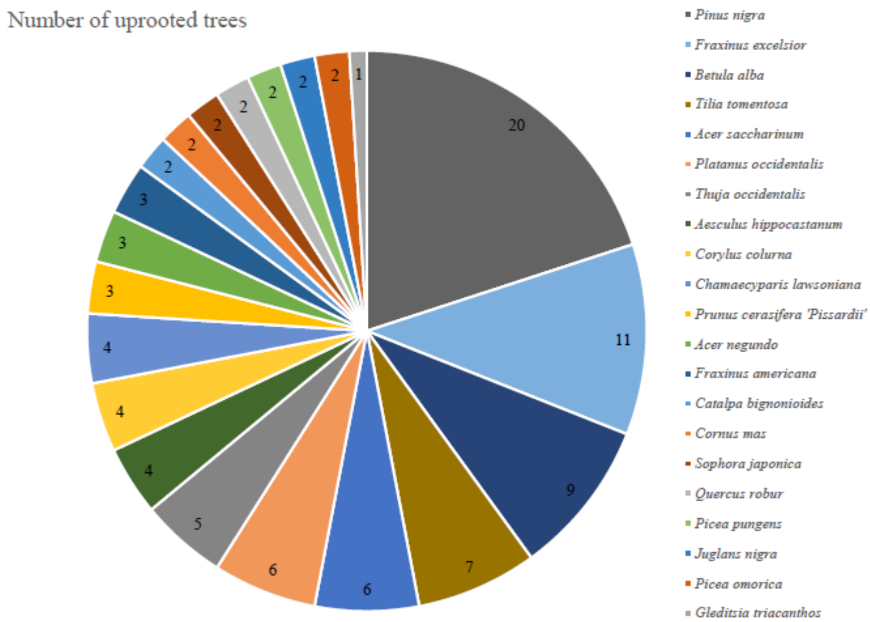


**Figure 5.** Summary of the number of uprooted trees observed by species in all three localities. Species are listed in decreasing order and presented clockwise.

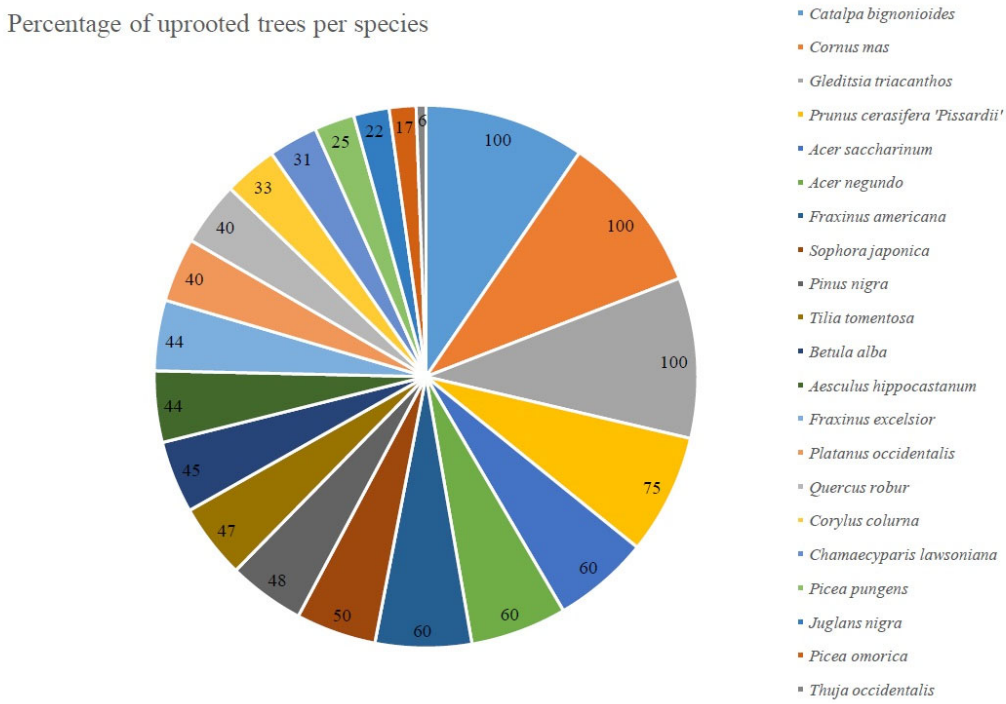


**Figure 6.** Percentages of uprooted trees observed by species in all three localities. Species are listed in decreasing order and presented clockwise.

Since the highest percentages of uprooted trees were associated with a low number of specimens, the data from Figures 4 and 5 should be interpreted concomitantly. Namely, uprooting with 100% incidence was noted for *C. bignonioides* and *C. mas*, represented by two specimen trees, as well as *G. triacanthos*, represented by only one tree.

Considering the top ten scoring for both calculations, *P. nigra*, *B. alba*, *T. tomentosa*, *F. excelsior*, *A. saccharinum*, *P. occidentalis*, and *P. cerasifera* were the species that showed a lower resistance to hurricane-strength wind, with both a significant number and percentage of uprooted trees.

## 4. Discussion

The main purpose of this research was to assess trees' monetary loss in the public green spaces in Futog, one of the towns most affected by the supercell storm that hit the territory of Northern Serbia in the summer of 2023, concomitantly highlighting permanent social, environmental, and economic losses. The three investigated public green areas (two educational areas and one park), comprising less than 5 ha (44,588 $m^2$), experienced a total loss of almost half a million Euros (EUR 495,864) when expressed in the national nursery prices as well as more than 1.5 million Euros according to the European price levels (EUR 1,528,481). While this monetary value is understandable to both highly and lower-educated citizens, regardless of gender, race, religion, minority dependence, seniority, or any other discriminating element, there are much greater losses about which there is a need for raised awareness among engineers, practitioners, and users.

Considering that economic losses are only one of the three pillars, social and environmental irreversibility must be taken into account. Total canopy volumes (calculated from the crown heights and widths) of the uprooted trees amounted to 30,333 $m^3$, indicating that 0.7 cubic meters of green mass were lost per one square meter of the investigated public spaces. This implies that some of the most important ecosystem services, corresponding to the mentioned social, economic, and environmental pillars, were irretrievably lost. Provisioning, regulating, cultural, and supporting services affected by the uprooted trees are presented in Figure 7.


**Figure 7.** Potential ecosystem services losses from three analyzed public green areas due to the determined species representatives being uprooted.

From the analysis of dozens of publications, it was determined that all types of ecosystem services are significantly influenced by factors such as leaf area and morphology, as well as crown dimensions, diameter at breast height, and tree height [37], investigated in the present study. At the same time, these features are crucial for wind resistance. The influence of the canopy shape and size on the uprooting of trees due to wind blows is a multifaceted interaction, involving various factors that have been explored in the field of tree biomechanics and urban forestry. Canopy characteristics play a pivotal role in determining a tree's vulnerability to uprooting during high winds [38,39]. Larger canopies expose a greater surface area to the wind, increasing aerodynamic forces and the risk of uprooting. The weight distribution within the canopy is crucial, with symmetrical canopies generally offering better aerodynamic properties [40]. The species-specific characteristics of trees also contribute significantly to their wind resistance [41]. Different tree species have evolved specific adaptations to environmental conditions, influencing their aerodynamic properties and resilience [42]. However, species that were noted for the highest or medium–high wind resistance to the several hurricanes in the United States coastal areas (such as *Acer*, *Betula*, *Fraxinus*, and others) by Duryea et al. [38] were not confirmed as wind-resistant in the present study, implying that this criterion cannot be solely taken into account. Furthermore, trees belonging to one species did not perform in the same way in all three investigated areas (for instance, birch trees fell in two out of three investigated green spaces, while Serbian spruce trees fell in one out of three spaces). Frankly, understanding the complex relationship between wind forces and tree stability requires considering the overall health of the tree, its canopy characteristics, and the surrounding environmental conditions. Based on the available literature survey, Salisbury et al. [43] classified those influences as biotic, abiotic, and management factors, with diameter at breast height (DBH) as the most frequently studied factor, while species influence was positioned as the second. In this review, root properties have shown significance only in rural studies. On the contrary, among 21 critical variables when estimating green space vulnerability to typhoons, Nguyen et al. [44] considered both the canopy characteristics and root–soil interaction in the prediction of uprooting damage. Exploring tree failure following a windstorm that occurred in Brewster (Massachusetts, USA), Kane [45] noted that the species, height, DBH, the presence of defects, and whether the trees had undergone pruning or if nearby trees had been removed affected tree uprooting. According to the same author, a critical wind speed (>30 m/s) is usually coupled with other factors such as precipitation, soil properties, and tree characteristics. Additionally, the health of a tree, including well-developed root systems and sturdy trunks, enhances its ability to withstand wind forces. It is clear that, besides the aboveground properties, the belowground characteristics (root spread, root architecture, soil type, and root-plate development) also influence wind resistance [46].

Soil conditions, such as type and compaction, also play a crucial role in tree stability during windy conditions [47]. Loose or waterlogged soils may increase the risk of uprooting, even for trees with well-designed canopies. This might be one of the major uprooting causes in the present study. As noted in the field survey after the supercell storm, documented in Figure 2b, although generally described as species with tap and heart root systems, the majority of the fallen trees had developed shallow roots, not balanced with their canopy sizes. As noted by Gardiner et al. [42] and Krišāns et al. [48], fatal tree failures under extreme wind loads are primarily determined by tree anchorage, especially the characteristics of the soil–root plate interface. As shown by Gardiner et al. [42], the very limited depth of the roots induced the uprooting of edge-standing Sitka spruce trees on wet soil. Due to the proximity to the Danube River and its inundation-prone nature, the town of Futog represents an area with a high level of underground water. We combined the available literature data on root system properties and obtained canopy measures to underline the possible uprooting causes. Notably, larger canopies (frontal areas >200 $m^2$) are required for the uprooting of species characterized by a heart root system, characteristic of *Q. robur*, *P. occidentalis*, and *T. tomentosa*, placed close to the linear correlation line in the scatterplot. On the contrary, segregated from the correlation line are species with an intrinsic tap root system, such as *S. japonica*, *F. americana*, and *P. cerasifera* 'Pissardii', impeded by high underground water levels, where even small canopy frontal areas were enough to exhibit more than 50% of uprooted trees. Smaller but still significant percentages of uprooted trees (30–50%), with variable canopy areas (10–150 $m^2$), also indicate that the expected intrinsic root system architecture was not achieved and that there was a significant misbalance between above and below ground biomass, enabling a 'shovel' effect and canopy failures.

In our study, *P. nigra*, *B. alba*, *T. tomentosa*, *F. excelsior*, *A. saccharinum*, *P. occidentalis*, and *P. cerasifera* were the species that showed a lower resistance to hurricane-strength wind, with both a significant number and percentage of uprooted trees. However, among these, *P. nigra*, *B. alba*, *F. excelsior*, and *P. cerasifera* are considered resistant according to the official catalog description. Mixed results related to the trees' characteristics and uprooting correlation might ultimately be a result of the wind speed, direction, and duration, which unfortunately was not predicted to happen and thus not investigated and recorded in the given three areas (only in general, >30 m/s). As stated by Duryea et al. [38], the percentage of urban trees loss is directly correlated with the wind speed. The same authors noted that their lists should be used with some reservations, bearing in mind that no species or individual tree is entirely immune to wind damage. Similarly, in our study, even the most adaptive and so-called 'climate trees' experienced more than 50% of uprooting (*C. bignonioides*, *G. triacanthos*, *A. negundo*, *F. americana*, and *S. japonica*). On the contrary, it can be noted that mainly young trees of the most invasive alien species in the continental climate, *C. occidentalis*, *M. nigra*, *R. pseudoacacia*, *R. pseudoacacia* 'Globosa', *T. occidentalis*, and *U. pumila*, were not affected by the storm event. Thus, with a developed protocol for their maintenance (obligatory generative potential exclusion and vegetative mass preservation), these species might be of the importance in future planning activities [49].

Proper greenery management supports successful thriving in altered urban ecosystems. Adequate pruning practices can influence canopy structure and reduce wind resistance area. Maintaining a tree by removing dead or weak branches can enhance its ability to withstand wind loads, which, in the cases analyzed in this paper, could partly be entrusted to the specialized teachers in the Agricultural High School and serve for horticultural educational purposes in their own schoolyard, supported by specialists from academia. As noted by Rolleston et al. [50] in 2023 there was a notable increase in climate-related catastrophes worldwide, thus proposed higher education institutions' involvement towards significant advancement of Climate justice through their research, education, community involvement, and public outreach. Besides teachers and pupils, engagement could consider other citizens, since investigated green areas have significant importance for all residents [51]. With such an approach, multiple sustainable development goals (SDGs) could be addressed simultaneously [52]. Education and involvement of all related groups—citizens, nursery producers, entrepreneurs, planners, and policy-makers—are some of the most important prerequisites towards upgrading green public areas to more sustainable and resilient ones (SDG11), concurrently ensuring the healthier life of citizens (SDG3) and biodiversity protection (SDG15), as well as the efficient use of natural resources (SDG12).

Due to climate change, the strong storms that hit Futog and the entire Vojvodina area in July 2023, which caused significant damage, will become more frequent. In this regard, it is necessary to enhance plants' adaptability by maintaining their health and condition at a higher level. The recent findings of Nguyen et al. [44] suggest the importance of appropriately managing urban trees to alleviate the impacts of climate change, especially typhoons' influence on urban green spaces. The prevention of losses rather than costly sanitation must be prioritized. In many cases, plants considered inadequate in urban green spaces must be replaced, especially those that generate more disservices than benefits [53]. In December of 2005, a devastating windstorm struck a limited area of Cape Cod in Massachusetts, USA, where, despite the relatively confined scope of the storm, wind speeds reaching approximately 45 m/s led to thousands of tree failures, incurring cleanup costs exceeding USD 1 million [33]. Similarly, in the present study, damage caused by a single storm in an area of less than 5ha, induced losses of 98 trees and EUR 495,864 (local prices) or more than three-fold (EUR 1,528,481) in international prices, with ongoing cleanup and costs that remain to be calculated. Although economic valuation will remain a crucial piece of evidence to support investments in urban tree planting and management, its practical application in landscape planning and design will necessitate further investigation into how it integrates with frameworks for making decisions [54].

In the face of climate change, in addition to protection and enhancement, we also need to consider insuring trees, given the losses that occurred during just one storm, and the estimated value of the currently thriving trees (EUR 396,480; 565,133; and 265,876 in the national and EUR 1,330,345; 1,697,561; and 875,148 in the international prices for the each of the three investigated areas). Due to the green area's significance (i.e., high school yard accompanying the Chotek Castle as valuable cultural heritage) as well as the presence of the currently undamaged 140-year-old *P. occidentalis* specimen under protection as a natural monument of the III category (The decision on protection 'Official Gazette of the City of Novi Sad' number 2/95 named 'American Sycamore in Futog'), tree appraisal should be considered as a basis for insurance in the case of future storm damage. The estimated value of this tree alone is EUR 31,647 (national prices) and EUR 91,575 (international prices) due to the impressive state and size (condition class of 0.8, tree height of 28 m, trunk height of 6 m, trunk circumference of 4.20 m and crown diameter of 24 m), urging its unequivocal preservation. A better understanding of the risk factors associated with tree species' susceptibility to severe storms is key to predicting and ensuring the future of forest ecosystems under climate warming [41].

Climate and environmental justice issues in Novi Sad and its adjusted settlements in the past few transitioning years were successfully recognized and significantly addressed, Including poisonous and allergenic specimens' assessment and management recommendation in preschools and schoolyards; invasive alien specimens' determination and management recommendation in highly visited streets and parks; public and private urban fruit production using disease- and pest-resistant cultivars; revitalization of neglected urban spaces through accessible pocket gardens; rain gardens [55] and green roof at the Special Education School 'Milan Petrović' [56] complemented with the current amenity tree appraisal, preservation, and insurance. Local governments must continuously monitor the indicators of urban greenery value and provide financial resources for maintaining the ecosystem services for all vulnerable groups of the population. Implementing NBS that can mitigate multiple challenges and correspond to vulnerable users' needs leads to a resilient and sustainable city green infrastructure [57]. Providing a 'peace of nature' in the dense urbanized areas to each resident regardless of gender, race, religion, minority dependence, seniority, or any other discriminating element supports climate justice basic principles [58,59].

## 5. Conclusions

Understanding the complex interplay between canopy characteristics, tree and root structure, and environmental conditions is essential for assessing the risk of uprooting during windy conditions. Arborists and urban planners must consider these factors when selecting tree species for urban environments and implementing measures to enhance tree stability, such as pruning and proper soil management. Additionally, the importance of a thoughtful approach to planning and designing the outdoor spaces of educational institutions, including the careful selection of plant species, due to their users' vulnerability, is undeniable.

The total appraised monetary loss as a consequence of the supercell storm according to the tree appraisal method in a territory of less than 5 ha amounted to almost half a million Euros (EUR 495,864) when expressed in the national nursery prices as well as more than 1.5 million Euros according to European price levels (EUR 1,528,481). The correlation analyses showed that no single tree's characteristic could explain the uprooting incidence alone, but indicated that both belowground and aboveground biotic (morphological and physiological), abiotic (environmental), and artificial (root and canopy maintenance) factors, to be further investigated, might influence the wind-caused losses. Since no species-specific responses to the wind-caused damage could be observed, except for the invasive ones (*C. occidentalis*, *M. nigra*, *R. pseudoacacia*, *R. pseudoacacia* 'Globosa' *T. occidentalis*, and *U. pumila*), root system and canopy maintenance measures applied towards preventing uprooting are of the utmost importance. Advocating for mutual action towards resilient planning aligned with climate justice principles, this study convokes all interested parties (teachers, parents, citizens, landscape architects, horticulturalists, biologists, socialists, and environmental economists) to take part and co-create institutional green areas on the scientific and practical foundations provided by academia.

Prevention due to the direct economic, as well as indirect ecological and social, losses considering the safety of the greenery users, especially the most vulnerable part of the population, must be highlighted. Invaluable human losses in this study were avoided since the storm occurred during the summer school vacation, making this study an alarming warning for both canopy and root health inspection and proper management. From an economic and environmental point of view, the insurance of the currently unaffected solitary specimens of an excellent appearance and ecosystem services provision should be initiated and promoted, taking into account and monetizing all possible services, be they present or future.

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