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Handbook for non native tree species in the Urban Space

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MANAGEMENT OF NON-NATIVE TREE SPECIES IN URBAN AREAS OF THE ALPINE SPACE

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FOREWORD I
FROM THE STRATEGY TO THE TREES AND BACK

Tina TRAMPUŠ

Our world and the dynamics of our planet are becoming increasingly unpredictable. Yet in our reality, we are developing more and more plans and strategies, attempting to map out our future. It is certainly important to discuss such plans – but are we actually living them as well?

Within the EU Strategy for the Alpine Region (EUSALP), Action Group 7 focuses on developing ecological connectivity and green infrastructure in the Alpine region. Ecological connectivity is the desired quality of our open space, and most stakeholders agree about it – at least at the strategic level. At the implementation level, a better understanding of the topic as well as of the issue of invasive plant species still appears to be needed. To put it simply: (Fast) spreading of alien species is the most pressing problem, and ecological connectivity can exacerbate it. Therefore, when we know enough about the biology of the respective species, it is useful to jump back and forth between the strategic level and the practical level on the ground to determine whether the implementation of a strategic objective actually leads to the desired future.

So, how can we manage invasions? How do we manage existing or potential sources of "contamination"? This presents an even greater challenge in the real world, where there are rules on free trade and consumer rights as well as desires for immediate availability of goods and services that are new, exciting, exotic, etc. The situation in cities is more specific and perhaps more controllable, especially when talking about a limited number of invasive plants growing within defined green areas, where spreading is nearly impossible (or made impossible by management). But even here the devil is in the details, and we should be aware of the potential risk of dispersal along water corridors

and by birds. Is it even possible to ensure ecological connectivity for desired species (small mammals, insects, fish, etc.) while maintaining full control over invasive ones?

Understanding both the grand strategic objectives and the practical local goals also makes apparent the differences between the two. In terms of strategies, we are talking about long-term and slow processes. But the reality of invasive species is all about short-term and fast developments – in other words, the exact opposite. A difference in values becomes recognizable as well: Many exotic species were brought to Europe because they served our desires (though not necessarily our needs) by being special and fast-growing. They allowed us to enjoy tall, magnificent trees in the limited timeframes of our lives – or to have forests that produce more wood, trees with more beautiful colours, more flowers for bees to produce honey, and so on. Little was known about the invasive character of these plants several centuries or even just a few decades ago – and even if we had known, would anyone have cared? Putting aside the issue of the current spread of invasive species and focusing on their sources, the question is still relevant today: Are we willing to stick to the native species that nature has provided us with in a given location and plant (slow-growing) trees whose full splendour will only be enjoyed by future generations? Are we prepared to change the conditions in urban areas (less traffic, less concrete, less use of salt, etc.) to keep them habitable for native species? What values do we intend to stand for? What is our desired future and our "strategy for survival"?

Long-term planning should always go hand in hand with regular reality checks on the ground. Conversely, at the local level, we often need to broaden our focus and evaluate how our activities tally with the greater perspective and our desired common future. Paraphrasing Dwight D. Eisenhower's famous quote to state that "strategies are useless, but strategic thinking is everything", we can perhaps agree that it is important to have a vision while still remaining grounded in reality. And the reality is that our planet continually provides us with unpredictable challenges and new opportunities for the co-existence of all living beings.

FOREWORD II

Aleksander MARINŠEK, Katharina LAPIN

In 2021, the International Panel on Climate Change (IPCC) published a report in which scientists stated among other things that the average global atmospheric temperature around 2030 will be 1.5 °C higher than in pre-industrial times. The IPCC's projections or scenarios are based on models as well as on future trends in society. Accordingly, the most optimistic scenario currently predicts warming by just under 2 °C by the end of the century – the most serious warning to the world to date.

There is a real possibility that we have already crossed a threshold where sudden changes could be upon us in a very short time. As for the impact of the predicted changes on the Alpine space, we can already anticipate what to expect. Heat waves, for example, will affect everyone and everything living in the Alpine space – and us humans not only directly, but also in terms of agriculture, forestry, health, tourism, and general well-being. There will be more floods, droughts, and green winters. According to climatologists, recurring droughts in particular will constitute a relatively new issue in the Alpine regions, and we are far from prepared for them. What can we do? Firstly, we need to end our dependence on fossil fuels and reduce our carbon footprint. The second step, which necessarily must also be drastic, is to adapt to what we already have and what we can expect – in every aspect of our lives, including urban living.

Living in cities is obviously very comfortable, as all types of goods and services are available to us. One of the perhaps most underestimated luxuries in this regard is green infrastructure in cities and other urban areas. This green infrastructure includes everything from parks, private gardens, and trees lining roads to green roofs and walls – essentially, anything that helps to absorb, delay, and treat stormwater, thereby mitigating flooding and pollution downstream. At the same

time, green infrastructure offers significant aesthetic value, and it also absorbs carbon dioxide, thus helping to reduce our carbon footprint. A single large, healthy tree can remove more than 150 kg of carbon dioxide from the atmosphere each year. Finally, greenery increases property values, especially in the immediate vicinity of parks and other green spaces.

Urbanized areas act as heat islands that experience higher temperatures than their surroundings. Man-made structures, including buildings and roads absorb and re-emit the sun's heat more than natural landscapes such as forests and bodies of water. For this reason, trees and urban forests are essential in built-up areas: They provide numerous ecosystem services and make our lives easier and more pleasant. In addition, they can help to lower energy consumption and reduce energy costs for heating and cooling: Trees placed around homes to shade windows result in high energy savings. They also provide evaporative cooling through their leaves, which increases air humidity. Shaded areas are cooler, and evapo-transpiration can lower peak summer temperatures by two to nine degrees. And in cities that have considerable problems with flooding, trees can mitigate this risk since they intercept around a third of the rainfall that hits them. Urban trees also reduce particulate matter less than 10 micrometres in diameter (PM 10) by 0.1 kg per tree per year, and they diminish ozone and sulphur dioxide as well. All of these ecosystem services could be enhanced by increasing tree density. It is obvious how essential trees are and will be in the future for coping with and adapting to difficult climate changes.

From the point of view of managing tree species, it is very important for each city to have its own green infrastructure strategy and plan to implement.

Changing climate factors – and especially the occurrence of droughts – will dramatically affect tree habitats in cities. For most tree species, the urban environment already represents an extreme habitat with limited growing space, shallow soil, nutrient deficiency, higher soil and air temperatures, and the presence of salt and pollutants. Trees are also often exposed

to various forms of mechanical damage in city environments. Therefore, urban trees should be selected for their durability and resilience, character, growth habit, and aesthetic value. Urban forests should feature a diversity of species and avoid monocultures, which are less resistant to pests and other environmental factors that can damage or kill trees.

Many native trees in the Alpine region such as *Fraxinus ornus*, *Acer campestre*, and others have proven to be very suitable for the harsh environmental conditions in cities. However, cities have always been places where a wide variety of native and non-native tree species were planted. In the course of the ALPTREES project, we found more than 520 non-native tree species growing within the Alpine space, mainly in urban areas. This will likely not change in the future, and our most pressing task is therefore to identify which tree species are (still) suitable for sustainable and responsible use and management in urban areas. Non-native tree species can be part of the solution for adapting to changing climatic conditions, and the aim of this handbook is to offer information and assistance for making the right choices.

Figure 1: *The Alpine space (approximately 450,000 km2) consists of 48 regions and is home to around 70 million inhabitants.*

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IMPACT OF CLIMATE CHANGE ON URBAN TREES

Martin BRAUN, Katharina LAPIN, Dmitry SCHEPASCHENKO, Andrey KRASOVSKIY, Florian KRAXNER

Projections show that climate change will have a considerable impact on trees in urban areas by altering the frequency, intensity, duration, and timing of precipitation, drought events, non-native species invasions, insect and pathogen outbreaks, wind and ice damage, and landslides.[1] Trees are believed to have limited adaptive capacity to respond to extreme temperatures and rapid climatic and environmental change.[2] Furthermore, climate change is expected to be one of the main future causes of biodiversity loss worldwide,[3] and research projects that extinction of species from numerous taxa will follow.[4] By now it is widely accepted that climate change is a global problem, that CO_2 emissions are the main cause of climate change, and that deforestation is currently responsible for almost 20% of the annual global carbon dioxide emissions.[5]

Environmental conditions are generally more challenging for trees in cities than in forests[6] due to different microclimatic conditions, greater heat, pollution, and salt contamination, poor soil quality, and limited access to water. Trees are often selected according to their adaptability to these conditions.[7] The urban microclimate is characterized by higher ambient air temperature (the heat island effect), lower relative humidity, reduced wind speed, and higher pollution levels.[7] Urban trees play an important role in mitigating climate change impacts through a variety of ecosystem services like regulating air temperature[8] and producing and controlling air humidity[9] as well as providing recreational, social, and aesthetic benefits.[10] In cities, adaptation to future conditions is crucial for ensuring healthy living conditions

for the inhabitants.[11] This can be achieved with urban green infrastructure such as parks, green spaces, gardens, green roofs and walls, and roadside vegetation.[11] [12] [13] [14] Specifically, vegetation can improve the urban microclimate by diminishing the urban heat island effect and reducing air pollution.[12] [14] [15] Trees in cities can also reduce atmospheric CO_2, improve water quality, reduce erosion, mitigate channelling of winds, increase biodiversity (especially in parks and green spaces),[12] [16] [17] [18] [19] and act as buffers during heavy rainfall events.[15]

Adaptation requirements for urban trees

Non-native trees are sometimes viewed as part of a solution for adapting urban green spaces to future climate conditions. Bioclimatic envelope modelling[20] [21] can help to provide an initial assessment of non-native tree viability under future climatic circumstances. Subsequently, factors such as biotic interactions, soil conditions, extreme sites, evolutionary change, and the dispersal ability and adaptation potential of native tree species to future climatic conditions need to be adequately considered,[20] [21] [22] as does the fact that most trees in urban green spaces are not of species that would naturally occur in the region.

Urban trees are thought to be more vulnerable to climatic change due to their more extreme climatic environment, thereby necessitating adaptive measures with regard to tree selection. This increasingly makes non-native trees potential candidates for urban applications in the future. In general, climatic variability is considered to have more severe effects on trees than steady but small changes.[2]

The most critical parameter for urban trees seems to be drought tolerance. Depending on site conditions, tolerance to waterlogging and shade can also be important. High tolerance to one of these parameters generally tends to correlate with lower tolerance to at least one of the others.[23]

Depending on the location, greater uniformity of trees may be desirable (e.g. for streets or boulevards), whereas an ecological focus may necessitate selection of non-traditional species to promote a higher level of biodiversity.[24]

According to Brune,[7] taking crown shapes and sizes, growth rates, and potential life spans into account is likewise important. Greater diversity can make urban trees as a group more resilient to pests than uniform cloned trees.

Fast-growing non-native plants may have less dense tissues and therefore grow and incorporate carbon in their tissues faster than native plants. But they also decompose faster, accelerating carbon cycling and releasing carbon back into the atmosphere much more quickly. On the other hand, faster decomposition can increase biodiversity by increasing the abundance of herbivorous insects and soil microorganisms feeding on live and decaying plant tissue.[26]

Contrary to the introduction of non-native trees in forest ecosystems, where caution is advised with a view to potential long-term adverse effects on carbon and nutrient cycling as well as on established species in the Alpine space, introduction in urban spaces seems to be less critical due to the long history of the selection and use of non-native trees in urban areas. According to Brune,[7] high genetic diversity and phenotypic plasticity are desirable features for urban trees to increase resilience to future climatic conditions. Non-native trees for urban use should be specifically selected for local conditions, such as species from semi-arid regions for dry conditions or shade-tolerant species for areas with tall buildings.[26] [27] Observation of the site adaptation of non-native trees[28] as well as their effect on their new habitat[29] is essential. In summary, the following steps are necessary for managing trees in the urban environment:[8]

- Selection of appropriate species for current and future climate conditions
- Comprehensive site assessment
- Improvement of site conditions to ensure successful tree
- establishment
- Use of seedlings with suitable provenance and quality
- Long-term strategy for adequate planning and management

ALPTREES modelling approach for tree species suitability in urban areas

Computer models are used to simulate how different tree species grow in terms of quality and quantity. These models are generally flexible, fast, and low-cost tools for determining tree management options as compared to field or laboratory studies. Models can also be used to examine scientific hypotheses regarding causes and effects, as well as to determine connections between tree growth and a large variety of parameters including water resources, soil conditions, and temperature. Such models typically vary in their conceptual framework, input requirements, predictive goals, mathematical algorithms, applications, user support, and required user investment.[30]

Among other things, applying tree modelling to urban areas over time is useful for selecting appropriate species for available planting sites, anticipating future tree maintenance and removal costs, and quantifying the various benefits provided by trees. Different city types usually require the development of tailored tree growth models based on comparable climate regions to understand the degree of variability for the same species in different cities (cf. [31]).

A specific ALPTREES approach has been developed in order to harmonize tree modelling approaches employed in Alpine forest areas, the city–forest interface, and the urban areas in selected cities of the Alpine space as much as possible. To assess the environmental suitability of tree species in urban areas with specific emphasis on current and future climate conditions, species distribution models (SDMs) (cf. [32] [33]) at a relatively high resolution of 1 x 1 km^2 were generated. A harmonized approach between forest and urban tree modelling is ensured by basing the SDMs on an improved preliminary modelling approach that has been applied across the entire Alpine space with a particular focus on urban areas.[34] A set of bioclimatic parameters for historical and future periods is used to support this approach.

Most importantly, a combination of measured ground-level information (city-specific tree cadastres) and data obtained from global observations by the ALPTREES crowdsourcing platform using the iNaturalist[35] online app will be combined to assess the current composition and potential future environmental suitability of tree species in urban areas.

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DROUGHT RESISTANCE OF NON-NATIVE TREES

Srđan STOJNIĆ, Claudia COCOZZA, Erna VAŠTAG

Unlike trees growing in natural communities, urban trees are subjected to additional human influences. They therefore struggle with complex stresses that are less present or even non-existent in forest ecosystems. These stresses commonly act simultaneously or sequentially, chaining a large pool of negative factors. For example, soil compaction caused by human activity reduces the capacity of urban soils to absorb water, inducing a water deficit in trees that in turn can deteriorate their vitality, making them more vulnerable to pest and disease outbreaks. Likewise, it is well documented that certain factors can generate both growth-stimulating and stress-inducing conditions at once.[2] Indeed, elevated CO_2 concentrations increase the photosynthesis rate in plants, leading to faster growth and production of aboveground biomass.[3] However, increased CO_2 concentration also decreases the transpiration rate,[3] thereby reducing convective heat loss and exposing plants to a higher risk of overheating.[5] Therefore, depending on the intensity and duration of these stresses, the health and growth rate of trees can be significantly reduced. Moreover, as a consequence of the harsh environmental conditions in cities, the lifespan of urban trees is frequently shorter than that of trees growing in natural habitats.[6]

Although the causes of urban tree decline are complex and involve various direct and indirect factors, drought stress has been determined as the main driver responsible for damaging trees in urban areas.[7] Drought stress occurs in plants exposed to low soil water availability and atmospheric conditions causing high evaporative demands. In terms of time scale, drought can be either short-term or long-term. Short-term drought usually lasts between a few weeks and a few months and primarily affects young and newly transplanted trees that have not yet developed extensive root systems.[8] For example,

Gilbertson and Bradshaw[9] found that nearly 23 % of newly planted trees in the inner city of Liverpool died within three years of planting, primarily due to drought stress. Long-term drought corresponds to a precipitation deficit lasting longer than six months, which typically induces the formation of short shoots and radial growth decline,[10] and can trigger premature mortality in trees when it occurs cyclically.[11]

Tree species display a range of strategies for withstanding drought stress, from physiological and biochemical responses to modulation of their anatomy and morphology.[12] Physiological and biochemical adjustments occur inside plant cells and organs and commonly include stomatal control of water loss, reduction of leaf water potential,[13][14] and maintenance of water uptake through osmotic adjustment within the cells.[15] However, these mechanisms seem to depend largely on drought progress and its severity: under conditions of mild to moderate drought, stomatal closure is the major physiological response mechanism, causing decreased CO_2 availability in the mesophyll and reduction of the photosynthetic rate.[16] By contrast, however, stomatal control of photosynthesis seems to become progressively less effective as drought stress intensifies, and non-stomatal (i.e., biochemical and metabolic) limitations to CO_2 assimilation begin to prevail.[17] Furthermore, morphological and anatomical alterations such as reduction of leaf area, increase of leaf sclerophylly, and development of prolific and deep root systems have been recognized as key components of tree acclimatization to long-term drought stress.[18] As the drought resistance of trees is commonly based on two main strategies, namely drought avoidance and drought tolerance,[19] different tree species may have widely contrasting responses to drought-induced stress.[8]

Bearing these considerations in mind, the selection of suitable tree species for cultivation in urban areas should rely not only on their aesthetic qualities but also on an understanding of the complex interaction between the physiology of plants and their surrounding environment.[20] In such assessments a special emphasis should be placed to prevention of air

quality deterioration caused by emission of excessive quantities of biogenic volatile organic compounds (BVOCs) and their anthropogenic counterparts that greatly contribute to O_3 pollution.[21] Considering that BVOCs emission is sensitive to duration and severity of heat and drought stresses, the impact of trees is expected to increase in the future also from the perspective of air pollution control. Thus, taking the socio-ecological aims of urban forests into account, the selection of multifunctional tree species should be oriented toward mitigating negative effects of climate change and maximizing provided ecosystem services.[22] In this sense, both inter- and intra-specific diversity should be promoted to enhance the resilience of urban forests to environmental pressures and ensure the continued provision of functions relating to human well-being as well as landscape preservation and beautification.[23] [24]

Introducing non-native tree species (NNT) alongside drought-resistant autochthonous species has been identified as a possible solution for increasing species diversity in cities.[20] Although there is widespread concern that biodiversity loss may occur as a consequence of harmful effects of NNT on native species,[25] a recent study conducted in the UK showed that 75 % of respondents would be happy to see more non-native planting in UK public spaces if the selected species were better adapted to the changing climate than existing vegetation.[26] It is therefore likely that the relevance of NNT will increase under future climate change conditions, since public awareness regarding their role in securing the resilience of urban tree populations is rising. Accordingly, a number of studies have discovered evidence of higher drought tolerance of NNT growing in urban areas as compared to autochthonous species. For example, a dendroecological study conducted on several tree species cultivated along the streets of Dresden (Germany) showed that *Quercus rubra* and *Platanus* x *hispanica* are better adapted to warm and dry conditions than *Acer platanoides* and *Acer pseudoplatanus*.[27] Similarly, Vaštag et al.[28] reported that *Acer platanoides* trees growing in the urban area of Novi Sad, Serbia, exhibited a more severe reduction in physiological

performance than *Liquidambar styraciflua* when subjected to drought stress. Finally, using chlorophyll a fluorescence technique to study the state of the photosynthetic apparatus in young trees of eight species and cultivars in Warsaw, Poland, Swoczyna et al.[29] found that the three introduced species *Gleditsia triacanthos*, *Platanus* x *hispanica*, and *Pyrus calleryana* achieved the maximum quantum yield of photosystem II values approximate to optimum regardless of their distance from roads and the date of the measurements.

Even though the physiological condition of trees is closely linked to their capacity to provide ecological services in urban environments,[30] high tree biodiversity should be promoted to enhance the overall resilience of urban forests to biotic and abiotic stresses.[27] Moreover, as the stresses encountered by urban trees depend on growing conditions in urban areas (e.g., park trees and trees growing in urban woodlands are less affected by stress factors than trees occurring on squares), in tree pits, or along roads,[30] a variety of tree species including NNT and less commonly used autochthonous species should be considered for planting in urban environments. In this context, comprehensive guidance on the drought tolerance and growing potential of different tree species in various urban conditions should be developed for specific regions, including a list of traits that could be exploited as bio-indicators of those species' resistance to stresses.[8] [20]

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INVASIVE TREES IN URBAN AREAS

Katharina LAPIN

For centuries, cities have been flourishing centres of human life and trade as well as pathways for invasive alien trees. The 19th century in particular saw the establishment of numerous botanical gardens and landscape parks in which hundreds of exotic trees from Asia and North America were planted and admired by their visitors. At the time, unintentional spreading of these species was not considered at all, and in fact one of the primary interests was how to grow, trade, and reproduce such exotic trees for urban greening and other economic purposes. Since then, however, the phenomenon of tree species invasiveness has successively gained in importance due to the effects of climate change and the increase in available nutrients in urban environments. Almost 150 years after the boom in the introduction of alien tree species to Europe, concerns have changed considerably, and the invasiveness of some non-native trees has become a major issue for scientists as well as urban administrations.

Today, non-native trees (NNT) – introduced tree species whose origins lie outside the Alpine space – have become key elements of the urban green infrastructure. The ALPTREES inventory of NNT in the Alpine space identified 352 non-native tree species growing in parks, shading streets, or planted in gardens. This long list of alien trees contains mostly species showing no indications of having a negative impact so far, but there are also several (potentially) invasive tree species – NNT whose introduction, establishment, and/or spread poses potential or identified risks to native biodiversity, ecosystem functions, or socio-economic aspects including human health. While most non-native trees are maintained to provide various valuable ecosystem services including air quality improvement, carbon sequestration, cooling of urban environments, and aesthetic benefits, a few invasive species are already known to cause problems.

Municipal administrations worldwide are working to combat the dispersal of invasive trees to protect the biodiversity of peri-urban ecosystems, the urban infrastructure, and the health of their populations.

The Canadian poplar (*Populus* x *canadensis*), for example, has a well-developed root system and is known for rapidly growing to large sizes, which can be problematic if seedlings grow unnoticed on roofs or too close to historic buildings. The invasive box elder (*Acer negundo*) and tree of heaven (*Ailanthus altissima*) need to be managed every year along railway lines or metro stations, where they can interfere with the infrastructure. Furthermore, the pollen of many invasive trees can cause allergic reactions and other health issues.

Comprehensive management of invasive trees in cities should include the following steps:	
1	Identify impacts to define the management goal
2	Locate the invasive trees
3	Respect local legislation
4	Identify the pathways
5	Facilitate the prioritization of management actions
6	Plan and conduct the determined management actions with due consideration for stakeholder acceptance and cost efficiency
7	Establish long-term monitoring
8	Share positive and negative experiences

Established invasive NNT are generally easy to identify since they are present in large numbers and usually tolerate many soil types and spread easily. The tree of heaven (*Ailanthus altissima*), staghorn sumac (*Rhus typhina*), and princess tree (*Paulownia tomentosa*) are among the most widespread species in the urban areas of the Alpine space. Identification of potentially invasive trees that are not yet prevalent is much more challenging. Using experiences from other cities as well as technical reports and scientific literature, experts can often estimate weather a non-native tree species will be able to spread easily and in an uncontrolled fashion from the area where it was planted. Potentially invasive tree species such

as the Japanese angelica tree (*Aralia elata*) or honey locust (*Gleditsia triacanthos*) should be observed continuously in urban areas, since detection during the early phase of their spread to new habitats generally improves the cost-efficiency of necessary management measures.

Our experience during the ALPTREES project was that not only scientists and trained experts can observe and report the unintentional spread of potentially invasive trees. Every city inhabitant can join a citizen science community such as iNaturalist or other local programmes to report changes in the urban ecosystem. This helps ecologists and administrations to trace and estimate the development of urban flora and fauna and specify required management actions.

Although the problem of invasive trees in cities is much more topical today than ever before, it is obviously not resolved yet. Implementation of an early warning system and rapid transnational exchange on the arrival and management of invasive trees would be highly desirable. In the ALPTREES project, we have presented examples in pilot actions, workshops, and manuals to increase public awareness and local knowledge within an international communication network that is needed to deal with invasive trees in cites.

Invasive alien species: Invasive alien species(IAS) are animals and plants that have been **introduced** accidentally or deliberately into a natural environment where they are not normally found, with serios **negative consequences** for that environment.

Definition by the EU Regulation 1143/2014 on Invasive Species

Figure 1: *Populus x canadensis on the historic roof of St. Stephen's Cathedral in Vienna, (c) Lapin*

Figure 2: *Aralia elata escaping from gardens to urban forests. In the ALPTREES project in 2021, this species was successfully controlled during the early phase of its introduction.*

Figure 3: *Paulownia tomentosa and Ailanthus altissima in the city of Vienna.*

TREE HEALTH AND HUMAN WELLBEING IN TRENTO

Giovanna ULRICI, Gala CARANNANTE, Olga PARIS

It is well ascertained that urban green spaces can provide mental and physical health benefits to residents by offering psychological relaxation and stress relief, stimulating social cohesion, supporting physical activity, and reducing exposure to air pollutants, noise, and excessive heat.

Today, more than half of our planet's inhabitants live in urbanized environments – with Europe reaching peaks of 80 % – and it is clear that this trend will continue in the near future. The nature and character of our cities will be forced to change much more radically than is currently the case. If we aim to provide a healthy environment for people to grow in and relate to, then aspects connected to the improvement of health and wellbeing must be considered a priority when planning the cities of the future.

Scientific literature abounds with epidemiological studies showing that urban green spaces have various positive effects on human health, such as mitigation of depression and improvement of mental health, decrease of cardiovascular and pulmonary morbidity and mortality, and lowering of obesity and diabetes rates. The pathways leading to these beneficial effects of urban greenery are diverse and complex, and scholars have formulated various theories to explain the relationship between green spaces and health. In addition to aspects of health and wellbeing, future urban planning will also need to take into account the social aspects related to urban greenery. For instance, numerous studies have shown that socioeconomically disadvantaged people tend to benefit most from better access to urban green, whereas the areas they live in tend to feature limited availability of green spaces. Providing equal access to green areas is therefore an important goal of health-oriented urban policy, and it has become a recurring theme among the key objectives

addressed in international agreements and declarations over the past decade.

In this context, NNTs can amplify ecosystem benefits and services on the one hand (since they are more resilient than native species), while on the other hand they can also introduce new problems to human health directly (for example, allergies) as well as indirectly (destabilization of natural systems).

The urban green spaces in the City of Trento as case studies

We have seen that the presence of green areas in a city, such as parks and gardens of various types and sizes, produces an improvement in the quality of life that is observable in very concrete terms. In the case of Trento, for example, the trees on Piazza Venezia, one of the parks included in the busiest road ring surrounding the historic centre, absorb pollutants from the air and reduce ambient temperatures on hot summer days, while the park area itself offers spaces for recreation and sports, which studies have found to be beneficial to mental and physical health. Urban design should also take into account ecosystem characteristics, which must be evaluated according to local contexts and the actual needs of citizens.

Even though urban ecosystems cover a limited area compared to other ecosystems of the planet, their contribution is immensely important, as they are found precisely where their benefits can be enjoyed directly and easily by many people. For example, a strategically located park of substantial size – like Gocciadoro or the Piazza Venezia gardens – can lower temperatures by up to 3 or 4 degrees in summer by influencing the surrounding microclimate within a range of several hundred meters. This not only increases human comfort in the area directly, it can also indirectly produce positive economic repercussions by lowering costs related to the use of air conditioning as well as health care costs for summer illnesses. At the same time, such parks can function as open-air spaces for city events, as playgrounds and sports grounds, and as aggregation points, in which case their potential with regard to recreation increases while the potential for mitigating summer temperatures decreases somewhat. This trade-off situation helps us picture cities as mosaics of green areas with different specific functions – some more suited to recreation, others more effective for air purification or lowering temperatures.

Figure 1: *Map of urban green areas in Trento*

Census of the arboreal heritage of Trento

The municipality of Trento possesses an arboreal heritage of considerable importance, both from a quantitative and from a qualitative standpoint. The many species of plants found in

the area make the city welcoming and more liveable, not least from an ecological point of view.

The tree species in the city's public green areas have been the object of several censuses since the 1990s aimed solely at knowledge and classification: species, age, location, and dimensional characteristics. In 2016, with the introduction of an integrated system for census-taking, labelling, geolocation, and maintenance management, it was possible to begin a systematic collation of these data with knowledge on phytopathological characteristics, planning measures, and records of care and maintenance interventions.

At the end of 2017, the City of Trento launched the census of the arboreal heritage related to tree-lined avenues and trees in parks and gardens. This resulted in more than 270 tree species revealed: this is a very high number with regards to the urban public green trees, which makes the city of Trento rich in species and varieties. Among these there were native and non-native species, the most recurrent ones in the census data are shown in Fig. 2.

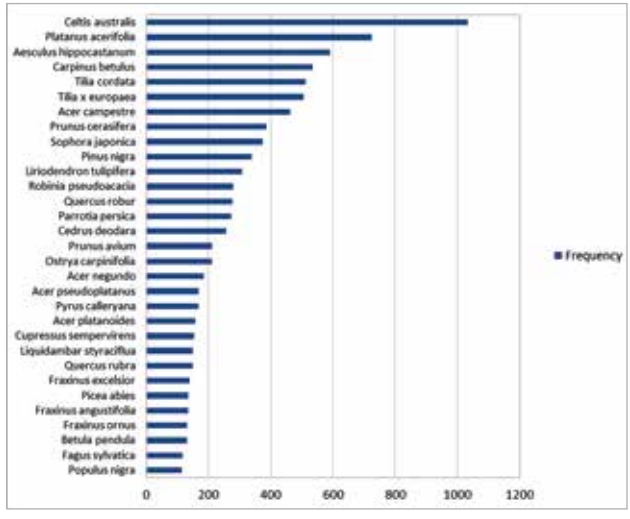

Figure 2: *Census of the arboreal heritage in Trento municipality.*

From the analysis of the species within the territory, it appears that NNTs currently make up around 45 % of all present species, thus representing almost half of the plant heritage of the City of Trento. The operational directives leading to the planting of NNTs in the urban areas of Trento are based on the respective species' characteristics, their ornamental value, and their mechanical strength and stability – especially their resistance to branch breakage, one of the fundamental aspects for ensuring public safety in urban environments.

In urban areas of the Alpine area, native tree species face multiple challenges: They are increasingly being affected by pests, diseases, parasites, and high temperatures due to climate change; for this reason, some tree species that currently play a role in urban green planning were thought to be unsuitable until a few decades ago. It is therefore important to develop growth strategies that include the presence of new tree species in projects designed to adapt to climate change as well as considering their future effects on society. NNT offer many benefits and provide new opportunities, especially by contributing to making urban greenery more resilient to climate change.

A particular challenge is the vulnerability of native tree species to new pests. Changing climatic conditions promote the displacement to and stable settlement in temperate belts of pests previously confined to more southerly, sub-tropical latitudes. In this scenario, possible adaptation measures include changes to tree planting and management practices, improved species matching, and the planting of NNTs resistant to these pests – once they have passed the control chain and received the Plant Passport according to Regulation (EU) 2016/2031 and Implementing Regulation (EU) 2017/2313.

Citizens and urban green spaces

For almost a decade, the citizens of Trento have shown an increasing desire to use shared and open public places and public infrastructures for activities with an intergenerational and intercultural character. This desire is met by the public infrastructures present in Trento, which provide possibilities

for engaging in various such activities. For this reason, the municipality of Trento has focused on the implementation of urban regeneration actions guided by the development and transformation strategies the city has adopted.

There is a multiplicity of initiatives resulting from direct collaboration between the municipal administration and citizens that are specifically carried out in open spaces with the aim of raising awareness among citizens by actively involving them in the care of the city's public gardens.

Among them is the initiative "Adopt a Flowerbed", in which citizens can "adopt" and care for a green area while receiving support and guidance from the respective organization in charge of its ordinary and continuous maintenance. A further programme is "Sport nel Verde", which promotes sports in urban green spaces equipped with ping-pong tables, volleyball and basketball courts, tennis courts, and bowls courts. This exhibits the parks as aggregative and recreational spaces in which citizens can spend time alone or meet new people, encouraging and stimulating the sense of belonging to the community and the city.

In addition to being an active operator, the City of Trento also promotes outdoor classrooms and environmental education projects carried out by other institutions operating in its territory (schools, cooperatives, environmental guides, etc.).

The initiatives described above highlight the potential of citizenship for reviving places and spaces. Citizens of different ages make use of urban greenery in different ways: alone, in the company of others, with the creation of local micro-economies or specific forms of "community welfare" in open spaces. In this context, Trento's urban green spaces assume a significant role for the urban and peri-urban areas comprising the nearby mountains and surrounding valleys, due to its environmental and landscape value.

Conclusion

The current practice is to encourage the planting of native species, citing their adaptation to local conditions and the need to maintain biodiversity and a native genetic base. However, native or naturalized species may not be able to adapt to climate change, especially given its increasing rate. Sourcing plants from regions with climatic conditions similar to those predicted by studies for local areas may provide a possibility to mitigate these effects; nevertheless, care must be taken to ensure plants posing the least possible risks are selected. Besides climate change, other factors must be considered as well to ensure that such planting is carried out appropriately with regard to place, time, and techniques.

In general, the criteria to follow when choosing which trees to plant are influenced by climate change and divided into three broad categories: design, site characteristics, and maintenance management. More specifically, the factors to consider in the case of trees for urban streets or parks are their response to pruning, stability, disease resistance, soil adaptation, tolerance of sun/shade, and absence of catastrophic pests. In the current scenario of climate change, NNT – if properly selected, surveyed, and managed – are often the most suitable choice for urban green areas.

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RECOMMENDATIONS FOR URBAN LANDSCAPE PLANNING

Giovanna ULRICI, Linda BONETTI

Introduction

Key points in the development of urban landscape planning:

- European, national, or municipal recommendations and guidelines;
- Importance of design and maintenance of urban greenery;
- Evolution of urban greenery with regard to climate change;
- European collaboration and coordination;
- Importance of public opinion with regard to the introduction of non-native species.

Studying the phenomenon of invasion and the management of non-native trees in the Alpine area is essential for preserving the delicate Alpine ecosystems; climate change and urban growth towards the Alpine forest areas require holistic action to understand non-native flora in all its aspects.

Although scientists have found that Alpine areas tend not to be in extremely close contact with non-native plant species, which are usually found at lower altitude levels, it is still important to study and understand the behaviour of these non-native plants, since their presence in the vicinity of Alpine forests may nevertheless allow them to spread to higher altitude regions.

A key aspect of research into non-native trees is understanding the uses and benefits that controlled introduction of these species can bring to an ecosystem. Although dangerous in some respects, they can also provide many biological and economic advantages: Their material can be exploited to build various products more efficiently, and their presence may become easier to manage over time thanks to climate change. During the past years, non-native trees have also been used for medicine, agriculture, and forestry.

The European Union has therefore funded the ALPTREES project within the INTERREG Alpine Space programme. The project covers the entirety of the Alpine area, aiming to coordinate joint action to ensure uniform management of the role of non-native trees within the Alpine flora.
ALPTREES brings together specialists from various sectors to guarantee that every aspect of non-native tree management is represented. And for the first time ever, it also places the focus of a European project on management of non-native trees in urban areas.

In 2007, the number of people living in urban areas exceeded that of people living in rural areas for the first time. The management of flora within the territories of cities, which are often home to millions of people, can become a very complex challenge. Different persons and pressure groups may have vastly diverse interests, and the introduction of non-native trees can divide public opinion regarding cultural, aesthetic, or health aspects. These differences of opinion among the multitude of citizens in cities lead to many challenges relating to homogeneous management of the introduction of non-native trees.
Urban greenery is "artificial" and ornamental greenery that simultaneously pursues the notions of extraordinariness (new species) and valorisation (native species). A very important feature of urban greenery is its multifunctionality, which requires diverse design choices, degrees of protection, and management rules given the multiple purposes that it can serve: It can have educational (school greenery), aesthetic (historical greenery, gardens), and social aggregation functions (condominium greenery, public parks).

Since research into the invasiveness of non-native trees is often carried out in forests or natural areas, we still know little about how non-native trees can settle and possibly invade native flora in urban areas, where the structure of the city itself may also encourage invasions given the various opportunities for meeting and exchange between people. This gives rise to further questions and challenges concerning the introduction of non-native trees into cities.

Another issue concerning the introduction of non-native trees in cities is the public opinion on them. Education and information are important levers that must be worked in order to interest and involve individual citizens in the subject of non-native trees and their introduction. Local authorities should therefore make every effort to inform and set an example in a clear and reproducible fashion.
Considerable responsibility in the context of the spread and use of non-native species also falls to the producers and retailers of ornamental plants. However, it is rare to find an informed and responsible nursery supply chain able to provide an adequate number and type of non-native plants; this is a problem underlying the use of non-native trees that needs to be studied and analysed in more detail.

Urban areas undoubtedly require non-native tree management approaches that differ from those applied in forest areas; specific attention must be paid to the way in which cities are built, to how existing rivers – natural features which, when joined with other natural or artificial transport carriers, can exacerbate invasion risks– are related to green areas, and to the problem of private land and what the respective owners want to plant. Another aspect hitherto overlooked by research is the role of climate change with regard to non-native species in urban areas. Only very recently have we begun to understand the benefits of urban forests at all, but we so far have only sparse knowledge of the effects of climate change on them. It is now widely known that climate change can cause stress to flora, and many plants have recently been observed to respond to the various stimuli derived from climate stress in complex and differentiated ways. Understanding the effects of climate change is therefore obviously a key tool to being able to manage non-native plants appropriately.

In recent years, more and more cases of invasions by non-native flora in urban areas have been recorded, shifting the focus to the issue of how to design guidelines for the introduction and management of non-native trees in urban areas to prevent conflicts between urban greenery and biodiversity along with the spread of non-native species into peri-urban

natural ecosystems. Examples of species such as *Robinia pseudoacacia* or *Paulownia tomentosa* spreading from cities to the surrounding woods are abundant; less apparent and well-known are the increasing suffering of "consolidated" species such as oaks lining roads in cities and the "silent" spread of *Ilex aquifolium* or *Olea fragrans* in urban gardens on the southern side of the Alps.
It must be remembered that urban greenery is extremely diverse in its functions and properties. Administrative bodies should attempt to identify weaknesses and potentials for the entire ecosystem rather than limiting themselves to management of the greenery within their strict competence. It is for this reason that public bodies promote and manage seasonal flower beds as well as parks, tree-lined roads, and historic gardens. In this context, the management of non-native trees includes various technical and cultural as well as regulatory aspects and is supported by centrally defined guidelines.

National policies concerning the management of non-native trees "must be based on a hierarchical approach which prioritizes the prevention of new introductions of species that are not specifically authorized, detection of and subsequent eradication in the case of new incursions, and possibly control and long-term containment when eradication is no longer viable, and the impacts caused by introduced species make this option necessary. Various local government instruments can also play a key role in defining guidelines for green development and the use of non-native trees integrated with the growth and transformation of the respective city.
The plan developed by the Italian Ministry of Environment and Protection of the Territory and the Sea, highlights the importance of coordination not only between Italian regions but also between the various European nations.

There is no doubt that Europe, as a union of nations wishing to create a common action plan, must establish criteria for the selection of urban greenery in terms of what can be beneficial to the local flora and what could cause damage to it.
The widespread belief that the use of indigenous plants offers the solution to most problems, as well as the application of

aesthetic criteria alone in the selection of ornamental plants, must be overcome in favour of:

- Proper design that considers implications for the urban, peri-urban, and extra-urban ecological balance with the purpose of enhancing the quantity and quality of ecosystem services offered by urban greenery. The importance of the quality of plants, the reduction of water requirements, the capture of CO_2 by the ecosystem, the responses of individual species in specific (especially road-related) contexts, and the levels of stability and security of tree species during extreme and anomalous events (which are increasingly frequent in the Alpine region) are just some of the key features that appropriate design must take into consideration. In this context, it is extremely important to know the origin of a plant's production, select suitable cultivars, and understand the constancy of response of clones.
- Proper maintenance that is aware of the consequences of bad pruning or care for plant physiology, as well as of the fact that the life cycles of plants in the urban environment are closely linked to respect for those plants and the symbolic and cultural values associated with them. Conscious management is the only way in which non-native plants can be introduced into a geographical area; in other words, they need to be accompanied by maintenance studies targeted at each individual species and potential situation.

The concept of adaptability is more important than that of diversity for protecting and managing both native and non-native plants.

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TURKISH HAZEL (*Corylus colurna*) – A CITY TREE FOR CHANGED CLIMATIC CONDITIONS

Olaf SCHMIDT, Katharina LAPIN, Isabel GEORGES

The Turkish hazel (*Corylus colurna*) has been planted in European cities for several decades as a popular street and park tree. Its relatively low site-related demands and high tolerance to heat and dust along with its uniform growth and associated aesthetic aspects are key reasons for its frequent use. In times of climate change, more and more attention has been paid to the Turkish hazel from a forestry perspective in recent years as well.[1] [2] [3] [4] Monographs on the Turkish hazel have been written by Alteheld[5] and Pauls[6].

Distribution and growth of the Turkish hazel

The Turkish hazel and around a dozen other Corylus species belong to the subfamily *Coryloideae*, which also includes the closely related genera *Carpinus*, *Ostrya*, and *Ostryopsis*. This subfamily, along with the subfamily *Betuloideae*, belongs to the birch family (*Betulaceae*). *Corylus colurna* is a Eurasian species naturally distributed across the Balkan Peninsula, along the northern coast of Asia Minor, and in the mountainous regions of Persia and Afghanistan, where it can occur at altitudes of up to 1,600 to 1,800 meters. In the Balkan region, it is usually found in mixtures with beech (*Fagus sylvatica*), hornbeam (*Carpinus betulus*), oriental hornbeam (*Carpinus orientalis*), Hungarian oak (*Quercus frainetto*), and silver linden (*Tilia tomentosa*). In the mixed oak forests of the Greek Rhodopes, it often occurs together with the silver linden on sites that are better supplied with water, for example in stream valleys and gorges.[7]

The species is characterized by exceptionally straight and regular growth resulting in a very compact pyramidal crown. It can reach heights of 25–30 m, crown widths of 8–10 m,

and trunk diameters of over 60 cm. The broad, ovate, doubly serrated leaves with heart-shaped bases are 8 to 12 (15) cm long, with a strikingly rich dark green colour that turns yellow in autumn. The inflorescences appear before the leaves emerge and are similar to those of the native common hazel (*Corylus avellana*). Because of the high allergenic potential of their anemophilous pollen,[8] it is advised not to plant alder, birch, or hazel trees in cities.[9] Although specific studies on the Turkish hazel are lacking, it can presumably be presumed similar to the common hazel in this regard, since the two species are closely related. The nuts of the Turkish hazel usually sit in clusters of two to eight (exceptionally up to 28) surrounded by a typical heavily slit and sticky pericarp. They are readily eaten by squirrels, and even the Eurasian nutcracker (*Nucifraga caryocatactes*) comes to the cities from the forests in some regions to harvest the nuts.[10]

Diseases and pests affecting the Turkish hazel

So far, the Turkish hazel has shown itself to be a very healthy, resistant species. In principle, it can be assumed to be affected by a similar spectrum of fungi and insects as the common hazel. This fact indicates the possibility of rapid integration of the Turkish hazel into European natural environments. In recent years, however, there have been repeated reports of vitality problems in the Turkish hazel, which manifest in increasing thinning of the crown and can ultimately lead to the death of affected trees.[11]

The most important pathogens infecting the Turkish hazel are probably plant-pathogenic bacteria of the genera *Pseudomonas* and *Xanthomonas*. They cause buds to dry out or sprout later in spring as well as lightening, spots, and eventual necroses on leaves, especially at the leaf edges. Shoots exhibit wilting symptoms and may die off entirely. In some cases, bark necrosis can develop, causing the bark to crack and cankers to form.[12]

The symptoms of affected trees are visible in a discoloration of their foliage during the growing period, which can lead to the death of individual branches or the entire crown.

Corresponding crown symptoms and conspicuous slime flow from the bark have been observed on Turkish hazels in northern Germany, for example in Göttingen and Vorpommern.[13] Infestation with the specific leaf fungus *Phyllosticta coryli* has been detected on the leaves of Turkish hazels as well.[11] [14] Ultimately, this infestation leads to premature leaf drop. A threatening endangerment of the Turkish hazel by *Phyllosticta coryli* cannot be assumed, however.

A certain species of plant wasp (*Craesus septentrionalis*) is known to attack birch and hazelnut trees as feeding plants; it can also occur on Turkish hazels. The polyphagous buff-tip (*Phalera bucephala*) is also known to occur very frequently and readily on hazelnut trees.[15]

The most important animal pest affecting commercial hazelnut cultivation is the nut weevil (*Curculio nucum*), which can cause a diminishment of harvests due to its reproduction in the nuts. Since fruit yield is not the main concern with the Turkish hazel, however, major problems cannot be assumed in this regard.

The hazelnut gall mite (*Phytoptus avellanae*) causes conspicuous galls in the shape of visibly thickened buds on hazelnut branches.[16] This does not affect the vitality of affected Turkish hazels, however.

Conclusion

To adapt to climate change, new tree species are being sought for use in cities as well as forests that can expand our current species spectrum in the face of higher average temperatures and lower precipitation. Turkish hazel is among the species that may represent potential alternatives, especially for urban green spaces. Overall, it appears surprisingly resistant to pests and tree diseases of all kinds. The spectrum of fungi and insects occurring on the Turkish hazel is very similar to that of the native hazelnut, with bacteria appearing to be the most dangerous pathogens. The Turkish hazel is an aesthetically pleasing tree species for the urban landscape due to its uniform growth, yellow autumn coloration, and large, tufted fruit clusters.

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CASE STUDY I:

NON-NATIVE TREES IN THE CITY OF TRENTO

Giovanna ULRICI, Gala CARANNANTE, Olga PARIS

The city of Trento possesses an arboreal heritage of considerable significance, both from a quantitative and from a qualitative standpoint. The many species of plants found in the area make the city welcoming and more liveable, not least from an ecological point of view. The agency responsible for the care and maintenance of Trento's green spaces is the Parks and Gardens Office, a department of the Roads and Parks Management Service. In late 2017, the city initiated a census of the arboreal heritage in terms of trees lining avenues and growing in parks and public gardens. This census identified of more than 270 tree species – a high number for an urban public space, making Trento a city rich in species and varieties.

Location of the City of Trento

The main activities undertaken by the Municipality of Trento include:

- Performance of the GIS census including cataloguing of the urban tree specimens.
- Sharing the local legislative, regulatory, and management framework relating to NNTs in the municipal area with other institutions managing greenery.
- Identifying two locations for the design and implementation of ALPTREES pilot actions.
- Initial qualitative survey of the general state of habitats and specific agronomic analysis of a Natura 2000 area.
- Educational activities for schools and citizens.
- Development of biodiversity laboratories in Trento's urban green areas based on pedagogic material developed in the ALPTREES project.
- Joining an NGO campaign for requalification and protection of the territory and adaptation to climate change. Through this urban reforestation program, 2,000 trees will be planted in the pilot areas.
- Creation of communication contents for presentation of the ALPTREES project and the use of the iNaturalist app.

The pilot actions performed in the city of Trento took

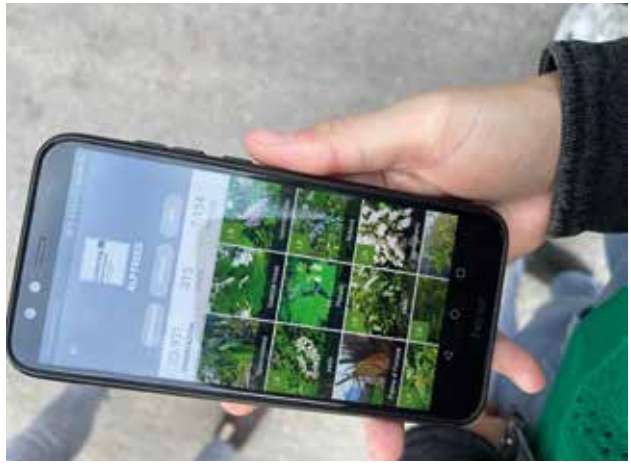

Figure 1: *PUsing the iNaturalist application for NNT identification.*

place in two different locations:

- **In Pilot action 1** relating to Gocciadoro Park, analysis showed that the best approach was to attempt to conserve the original tree species and contain non-native species.
- **In Pilot action 2** relating to the Canova quarter, a highly urbanized area, the inclusion of non-native species was determined to be beneficial, as they are more resistant to climate change and pollution.

Gocciadoro Park possesses considerable environmental value. At more than 20 hectares, it is the largest green space in the Trento peri-urban area, and thanks to its extraordinary richness of trees, it is partially protected as a "Natura 2000" conservation area. It is also a special area of conservation as stipulated by Directive 92/43/CEE on the conservation of natural and semi-natural habitats and of wild flora and fauna for the protection of animal and plant species habitats.

The site represents a residual core of fallen leafy mesophillous forest (Carpinus betulus and Quercus robur) on a hilltop, a vegetation type in decline throughout the Alpine space.

To analyse the dynamics in progress and plan the optimal strategy of management interventions within the park, a

"Management and Monitoring Plan for the Spread of Invasive Species in Gocciadoro Park" was drawn up. The main dynamics detected during the study of the park area are the following:

- Invasion by the particularly aggressive black locust (*Robinia pseudoacacia*), especially in areas with chestnut trees;
- Invasion by other ornamental allochthonous species, some of which are almost naturalized (bamboo reeds; renewal of palm trees);
- Anthropogenic pressure;
- Soil instability in steep slope sections.

The following management activities are therefore recommended: controlling of the black locust and tree of heaven (*Ailanthus altissima*) populations and progressive reduction of alien species; enhancement and conservation of mesophilic and mesohygrophilous broad-leaved trees, in particular English oak, beech, and oak, enhancement of some individuals of black and white hornbeam; conservation/enhancement of rocks with steppe vegetation and adjacent forest areas; mitigation of the causes of deterioration (anthropization, instability).

Activities in the Canova area included initiation of the CO_2 – Open Park project with the planting of non-native species. Located close to a suburb with a lack of public green spaces, this park will slowly develop on a patch of uncultivated land with stagnant water. The CO_2 – Open Park is intended for cooperative care by way of participation by city residents; it will also provide training and information on the benefits of greenery for mitigating the effects of climate change and promote projects and economic initiatives specifically targeting younger citizens (activities in the green care and implementation sector, didactic activities, animation activities).
This activity was combined with a series of plantings in the uncultivated public fragments, in part in the shape of rain gardens, with specific interventions including replacement and tree integration.

The overall proposal is to increase the city's green heritage and launch an educational campaign on the benefits of native

and non-native trees for mitigating the effects of climate change and increasing extreme weather phenomena (strong wind combined with irregular rainfall or intense precipitation, on trees weakened by unusually dry autumn and spring seasons or subjected to heat stress in heat island contexts) in the urban environment. Climatic data from the past decades were analysed for the purpose of planning appropriate tree planting activities.

The planting of non-native species within the Canova area serves as the first element of a design methodology to be replicated in other parts of the city. The project's goal is to improve the Canova area by offering social, environmental, educational, and experimental projects promoting the provision of ecosystem services as well as participation by citizens – in other words, by making elements of naturalness, rurality, environmental sustainability, sociality, inclusion, resilience, active citizenship, and physical and mental well-being accessible to everyone in the urban environment.

The primary outcome is a park functioning as a centre of aggregation, support, and social and environmental education for families and citizens from the neighbourhood through the planning and implementation of social participation activities. The project's expected benefit is the satisfaction of the needs mentioned above by involving citizens, families, neighbourhood schools, and various associations. It aims to create a lively and active centre of social, educational, and environmental enhancement, research, and experimentation in the field of sustainable lifestyles and urban settlements – an oasis where city residents can get in touch with nature, a laboratory of active citizenship and subsidiarity, and a space for families.

The current practice in many urban settings is to encourage the planting of native species, citing their adaptation to local conditions along with the obligation to maintain biodiversity and a native genetic base. However, native or naturalized species may not be able to adapt to climate change, especially given its increasing rate. Sourcing plants from regions with climates similar to the conditions predicted for Alpine areas in studies may offer a solution; however, care must be taken

to ensure that appropriate plants are selected to minimize associated risks. In addition to climate change, other factors must also be considered to assure that the planting is carried out appropriately with regard to place, time, and techniques.

In general, the criteria to follow when choosing which tree species to plant are influenced by climate change and divided into three broad categories: design, site characteristics, and maintenance management. More specifically, the factors to consider in the case of trees for urban streets and parks are the respective species' response to pruning, stability, disease resistance, soil adaptation, sun/shade tolerance, and absence of catastrophic pests. In the current scenario of climate change, NNT – if properly selected, surveyed, and managed – are the most suitable choice for urban green areas.
In conclusion, the pilot actions in the city of Trento took place in the context of two different management plans for non-native species within the territory.

In pilot action area 1
(Gocciadoro Park), the main activities were the monitoring and containment of non-native species, since the park is a protected area and the primary purpose of the pilot action was to conserve the natural habitats and protect native species.

In pilot action area 2
(Canova), on the other hand, non-native tree species were planted, since the area is located in a highly urbanized setting where non-native species offer greater benefits and provide new opportunities, contributing to making urban greenery more resilient to climate change.

In Trento, like elsewhere, there not a single catchall method for the management of non-native species; instead, each management program must be designed and implemented on the basis of an analysis of the risks and benefits for the respective area.

Figure 2: *Walking path in Gocciadoro Park*

CASE STUDY II: OPTIMIZING THE FUTURE OF URBAN FORESTS IN THE CITY OF KLAGENFURT

Regine HRADETZKY

Climate change has become an incontrovertible fact in recent years, with increasing average temperatures and their far-reaching effects perceivable in various contexts. Urban areas usually differ climatically from their peri-urban surroundings due to their structure, the heat-accumulating materials they are built of and the additional heat they generate through heating systems, industrial and vehicle

exhausts, and the like, and the reduced wind velocities within them. Known as the urban heat island (UHI) effect, this circumstance means that temperatures in densely built-up centres can be up to 10 K higher than in their peri-urban surroundings.[1] Combined with summer heat waves, this situation can quickly become dramatic.

The observed rising temperatures as well as increasing numbers of hot days (Tmax ≥ 30 °C) have a serious impact on the quality of urban life and may even negatively affect human wellbeing and health. Viable attempts to counter a city's UHI effects may include raising the reflectivity and albedo of urban surfaces like roofs, walls, or street pavements, reducing the sealed surface area in general, and utilizing the cooling effects of increased latent heat flow and evaporation by promoting inner city open water and vegetation. In this context, development and maintenance of a city's so-called "blue and green infrastructure" will play a crucial role in adapting to urban climate change.

Location of the City of Klagenfurt

The urban green network

Urban greenery is highly varied. It mainly represents the sum of all green areas such as public parks, private gardens, sports grounds, and cemeteries, along with connecting linear structures like roadside tree rows, formative single trees, hedges, or relic floodplain forests alongside brooks and rivers. All these structures and entities together form the "green network" of a city, which transitions into the suburban and peri-urban surroundings at the city's edges with their different patterns of settlement and dominance of green space and forests.

How to safeguard the ecosystem services of urban greenery?

The green network is multifunctional, and like any natural occurrence of greenery, it provides ecosystem services to urban inhabitants that are often taken for granted. Among these services, air purification by filtering out dust and pollutants, increasing oxygen and fixing carbon dioxide in biomass, providing easily accessible recreation and nature experiences, and microclimatic functions such as influencing the local water balance and temperatures can be considered the

most important – especially in urban environments.

However, that ongoing climate change and high urban temperatures can also be expected to have an impact on urban green infrastructure by affecting site conditions in a way that decreases their suitability for certain species. As a result, the maintenance of green structures as well as the continued provision of their beneficial ecosystem services may become uncertain. In light of current developments, it is therefore high time to develop strategies to increase the resilience of the green network on the one hand (for example by finding alternative species compositions for existing stands and securing their existence in the long term), and to develop additional new stands and green structures in order to strategically supplement the urban green network on the other. This is all the more important since projections predict that more than two thirds of the world population will be living in cities by 2050,[2] and special focus must be placed on coping with the urban effects of climate change so as to develop and create liveable urban environments providing all the services humans require for their wellbeing.

Whereas the role and importance of widespread and old-growth urban forests that are well-frequented, well-managed, and essential for urban recreation has already been investigated, less attention has been paid to the role of unintended urban green sites like abandoned rural areas or plots that have remained unused, undeveloped, and left to natural succession processes for several decades. Such urban fallow grounds or derelict stands with spontaneous species compositions are generally rather small, often abound with NNT species, and usually exist only for a few years before attractive land prices and construction activities override any other potential interests. However, some of these sites can be viewed as fully grown forests today; they represent valuable elements of the green network within densely built-up zones, and their likely valuable contribution to the urban microclimatic mosaic and other ecosystem functions and services deserves to be shown and considered.

The situation in the city of Klagenfurt

In the years 2018 to 2020, the international project "*Urban Climate Change Adaptation for Austrian Cities: Urban Heat Islands*"[3] employed an urban climate model to survey the local situation in Klagenfurt, Carinthia, and developed future climate projections for two Representative Concentration Pathways, RCP 4.5 (decreasing emissions after 2040 according to the Paris Target) and RCP 8.5 (worst case scenario). Several adaptation measures were simulated as well. The results show that compared to the recent period (reference period 1971 to 2000), the number of average annual hot days (HD, Tmax ≥ 30 °C) will increase from about 7.4 to 19.3 HD/a (RCP 4.5) respectively to 20,1 HD/a (RCP 8.5) in the period from 2021 to 2050. The long-term perspective for the years 2071 to 2100 predicts 25.0 HD/a (RCP 4.5) respectively 48.1 HD/a (RCP 8.5), clearly showing the urgent need for future urban compensation measures.

With reference to the period 1981 – 2010 the average annual number of hot days (HD, Tmax ≥ 30 °C) was 12.5 HD/a with a range between green outskirts and city centre from 2 to 21 HD/a. A simulation of several adaptation scenarios showed, that the number of hot days can best be reduced by so-called "white city measures" (doubling the albedo of roofs, walls, and streets) combined with so-called "green city measures" (increasing green roof area by 50 %, increasing the number of trees by 50 %, decreasing sealed areas and unvegetated pervious areas by -30 %), whereas the maximum achievable reduction was estimated at -9.2 HD/a (44 %), the average reduction at -4.5 HD/a (36 %).

Optimizing three urban forest stands

Based on the results of the "Adapt UHI" survey and using a similar urban model with a higher resolution (20 m x 20 m grid cells), we attempted to determine to what extent three urban forest stands can contribute to reducing heat and the number of summer days on a very local scale.

Focussing on the three pilot areas Kreuzbergl (30.12 ha) Schachterlwald (3.28 ha) and Forstgarten (0.87 ha) the main questions were:

1. Up to what distance from the forest stands can their effects be perceived?
2. What would change if the forest stands were cut down?
3. What effect could be achieved by afforesting two additional nearby sites likewise located within a densely built-up urban zone?

The forest stands were also mapped and based on the results and predicted climate change factors, management measures were recommended with a focus on long-term safeguarding of these stands against expected changing climate conditions, which may also include certain NNT species following an assessment process.

Figure 1: *(a) Kreuzbergl (30.12 ha), (b) Schachterlwald (3.28 ha), (c) Forstgarten (0.87 ha).*

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CASE STUDY III: MAINTENANCE OF TREES IN THE MUNICIPALITY OF MARIBOR

Živa BOBIČ ČERVEK

Aerial photographs of the city of Maribor reveal many green areas. Forests cover approximately 36 % of the municipal area, with protected nature areas and Natura 2000 sites together making up almost 16 % while parks and other green areas represent more than 5 % of the entire territory. Approximately 112,000 people live within the 147 km^2 of the city.

All of the city's green areas are digitalized in the municipal geographical information system, which is currently being prepared for an update to be completed in 2021. The new database will include a tree cadastre including all important attributes necessary for maintenance.

The Department of Municipal Services, Traffic, Environment, and Spatial Planning oversees the maintenance of all public green areas. Maintenance concessions are currently granted to two companies: One takes care of the parks and the other maintains the tree-lined avenues and roadside green areas. Prescribed guidelines and expert recommendations are used by competent services and contractors to plan, choose, plant, and maintain woody plants and perennials. Each year, up to 300 new trees are planted in public areas.

One of the greatest challenges faced by the city is the maintenance and management of the largest park – the City Park with its broad hinterland, which is demanding and generates high costs for several reasons:

- The oldest part of the park was designed in 1872. Since then, 120 different tree species have been planted, while some of the existing trees still date back to the beginnings of the park.
- The park is under considerable pressure due to its vicinity to the city centre: Events, picnics, and forbidden cycling in the natural environment regularly take place there.

Location of the City of Maribor

- The surrounding area generates typical as well as unique interactions with the park: There are natural forests and vineyards, which demand differing management approaches in zones that need to be adapted to various protective, recreational, and aesthetic functions.

Figure 1: *View of the City Park with its broader hinterland – 3D model*
(Source: Geographical Information System and Data Processing Section at Municipality of Maribor)

The Environmental Protection Services Department of the Maribor Municipal Administration cares for 44 trees protected by a municipal decree in 1992 due to their age, range, growing site, or rarity. The competent state institutions for protection of the natural and cultural heritage issue all necessary permissions for intervention and management. Over the past few years, information boards displaying facts on the individual trees as well as their history and characteristics have been installed. The most frequent among the 15 protected tree species is *Taxus baccata*. Since they have been planted regularly around homes and in the hilly countryside for more than 300 years, these trees are among the largest representatives of their species in Slovenia. Other less common tree species worth mentioning include *Sorbus domestica* in the Kozjak Mountains, *Sorbus austriaca* in the Pohorje Mountains, and a large *Paulownia tomentosa* in the city of Maribor.

Figure 2: *Acer negundo is one of the many non-native plant species in the City Park*

The management of non-native plant species lies within the responsibility of the Environmental Protection Services Department as well. Since 2017, inventories of non-native plant species have been compiled for the city area, the urban and peri-urban forests, the Drava riverbanks, and protected nature areas (natural features, Natura 2000 sites). In 2020, these inventories were performed as part of the ALPTREES project in selected areas in four different landscape types. Over the past years, eight non-native tree species have been added to the inventory list. The results are shown in the graph below.

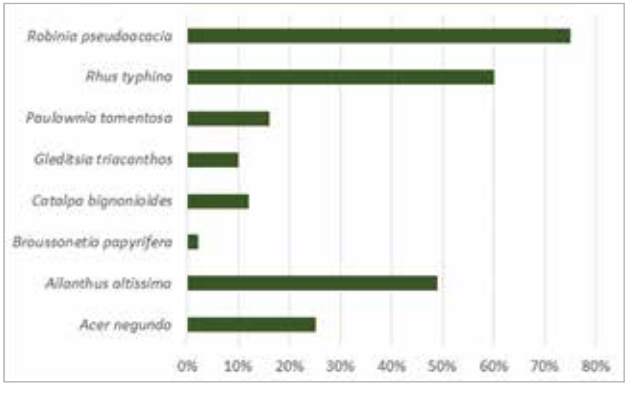

Figure 3: *Presence of individual non-native tree species in selected areas (% of all inventory areas)*

The city is currently faced with a relatively small population of non-native tree species that have been identified as invasive and could still be successfully removed. In order to prevent their further spread, efforts should be made to remove older specimens in particular, since our findings show that they represent the origin of expansion. However, the removal of invasive plants should remain focused on nature protection areas in order to preserve autochthonous plants. Increasing public awareness and improving the recognition of invasive plant species help to reduce the disposal of green plant material in nature and contribute to a more thoughtful purchasing of plants.

CASE STUDY IV: PERCEPTION OF THE DOUGLAS FIR BY FOREST VISITORS IN THE CITY OF FREIBURG

Katharina ABLER, Kristina WIRTH, Anja BINDEWALD, Tina GERSTENBERG

Introduction

Urban forests are valuable for people in cities because they offer excellent opportunities for recreation. This recreational value of forests is partly due to the perceived attractiveness of trees.[1] Little is known about the visual perception of and knowledge on individual tree species, however, especially with regard to controversial non-native tree species that are considered both useful and invasive.[2] The Douglas fir (*Pseudotsuga menziesii*) (Fig. 1) originating in North America, for example, covers 13 % of the entire urban forest area of the city of Freiburg in south-west Germany[3] (Fig. 1, 2). On the one hand, the species is considered invasive in Germany because it has spread into areas of high conservation value. On the other hand, its importance in forests may increase in future, as it is considered a suitable alternative to the Norway spruce under projected climate change conditions.[4][5] Against the background of this dichotomy, knowledge about forest visitors' perception of the Douglas fir may facilitate decision-making in urban forest management. Among other factors, the perception of this non-native tree species may be shaped by sociocultural context, knowledge of risks and benefits, and aesthetic preferences. The objective of this study was to investigate how the Douglas fir is perceived by forest visitors using the Freiburg City Forest (Stadtwald) as a case study location.

Location of the City of Freiburg

Figure 1: *Douglas-fir in the urban forest area of the city of Freiburg in south-west Germany.*

Figure 2: *The mountainous part of the Freiburg City Forest located in the Black Forest region in south-west Germany.*

Methodology

Perception of and knowledge on the Douglas fir in the Freiburg City Forest were assessed by surveying forest visitors online. Firstly, in addition to socio-demographic information, participants were asked about their educational background regarding the species. Secondly, tree species growing abundantly in the City Forest – including the Douglas fir – were presented individually on photos using a standardized form with an invariant background. Participants evaluated the trees with regard to their (visual) preference. In addition, several bipolar adjective pairs regarding "preference", "beauty", "stability", and "origin" were provided for rating the individual trees on an 11-point scale. For example, in the "origin" section, participants were asked to rate their perception of each tree species from native (1 point) to foreign (11 points). Subsequently, participants were asked questions regarding the socio-economic benefits and environmental impacts (positive and negative) of the main tree species in the City Forest, i.e. Norway spruce (*Picea abies*), Douglas fir, silver fir (*Abies alba*), European beech (*Fagus sylvatica*), and oaks (*Quercus petraea*, *Q. robur*). The online survey also included an open question about what aspects participants liked or disliked about the appearance of Douglas-fir. Finally, they were asked to map forest areas in Freiburg which they particularly like.

Results and discussion

Most of the participants (including laypersons) correctly identified the Douglas fir and thus exhibited the necessary knowledge to perceive it as such in the forest. Based on the image evaluations, the Douglas fir is visually preferred over the spruce and perceived as significantly more beautiful compared to other conifers. Overall, however, deciduous trees were preferred over conifers. The participants particularly liked tall Douglas firs with large trunk dimensions. Douglas firs are also common in locations within the City Forest that were mapped as favourite areas by the participants. It can therefore be assumed that the species is perceived as a constituent element of the urban forest. The fact that around half of the participants perceived the Douglas fir as "rather not foreign" or "not at all foreign" is consistent with this observation.

From an economic point of view, the Douglas fir is perceived better than the Norway spruce and silver fir. Consistent with this, the tolerance of Douglas-fir to drought, its wood value, and resistance to damaging insects is perceived to be higher compared to Norway spruce and silver fir. While experts in particular attribute a high climate protection performance to the Douglas fir, they assess it relatively critically from an ecological point of view, for example regarding the perceived impact on native biodiversity.

Conclusion

Overall, the results indicate that the Douglas fir is beneficial for the aesthetic value of urban forests. However, to address concerns regarding possible negative impacts on native biodiversity and maintain a high recreational value, forest managers may continue cultivating Douglas-fir in mixture with other tree species.[6]

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CASE STUDY V: NATURAL DISSEMINATION OF NON-NATIVE TREES FROM PARKS TO MANAGED FORESTS IN PREDDVOR TOWN

Aleksander MARINŠEK, Ana DOLENC

Introduction

Most of the non-native trees (NNT) in the Alpine space can be found in urban areas, primarily in parks and private gardens. These parks and gardens thus represent non-native tree species pools from which NNT can spread into neighbouring ecosystems such as meadows and forests. Some planted NNT persist only temporarily as casuals in the new area, while others can overcome local abiotic and reproductive barriers to establish self-sustaining populations.[1] [2]
The aim of this study was to survey the number and amount of NNT in an area where many NNT are planted. In addition, we intended to estimate the potential NNT propagule pressure and dissemination to the neighbouring managed natural forest.

Location of the City of Preddvor

Methodology

The study was conducted in an urban managed forest in the town of Preddvor, which is part of the Municipality of Preddvor located in the central area of the Gorenjska region in Slovenia. Forests cover more than 74 % of the Municipality. Preddvor is an old, small town first mentioned in written sources in 1147 as Niwenhouen. It is bounded by the river Kokra and Lake Črnava and by 4 castles – Preddvor Castle, Pusti Castle, Hrib Castle, Turn Castle. Based on existing data and expert knowledge of the area, we decided to study the park surrounding the medieval manor known as Hrib

Castle, where NNT were planted by the former owners (Zone A in Fig. 3). They assembled a collection of various exotic and native tree species, most of them coniferous (*Sequoiadendron giganteum*, *Pseudotsuga menziesii*, *Pinus strobus*, *Thuja occidentalis*, etc.), with a smaller number of deciduous trees (*Fraxinus americana*, *Quercus rubra*, etc.).

Figure 1: *Aerial view of Hrib Castle and surrounding park.*

We reviewed existing data on NNT in the municipality using the application Invazivke.si, an information system on non-native species that includes data gathered by means of citizen science as well as several national sources. The database and application were developed by the Life Artemis project.[3] Since the data obtained from this source were scarce, we decided to conduct an on-site survey of the existing NNT. We surveyed all NNT in the park, separating them

into four height classes to estimate their natural rejuvenation. A small part of the study area was surrounded by a fence and therefore omitted from the analysis.

For the survey, we examined the entire selected park area (Zone A in Fig. 3). We also inspected a nearby section of managed forest (Zone B in Fig. 3) for any presence of the determined NNT or signs of their rejuvenation[3]. We recorded all discovered NNT, entered them into the Invazivke.si application, and classified them into 4 four height classes: up to 50 cm, 50 to 150 cm, 150 to 500 cm, and larger than 500 cm (including mature trees). We subsequently used statistical tools and ArcGIS to analyse the data.

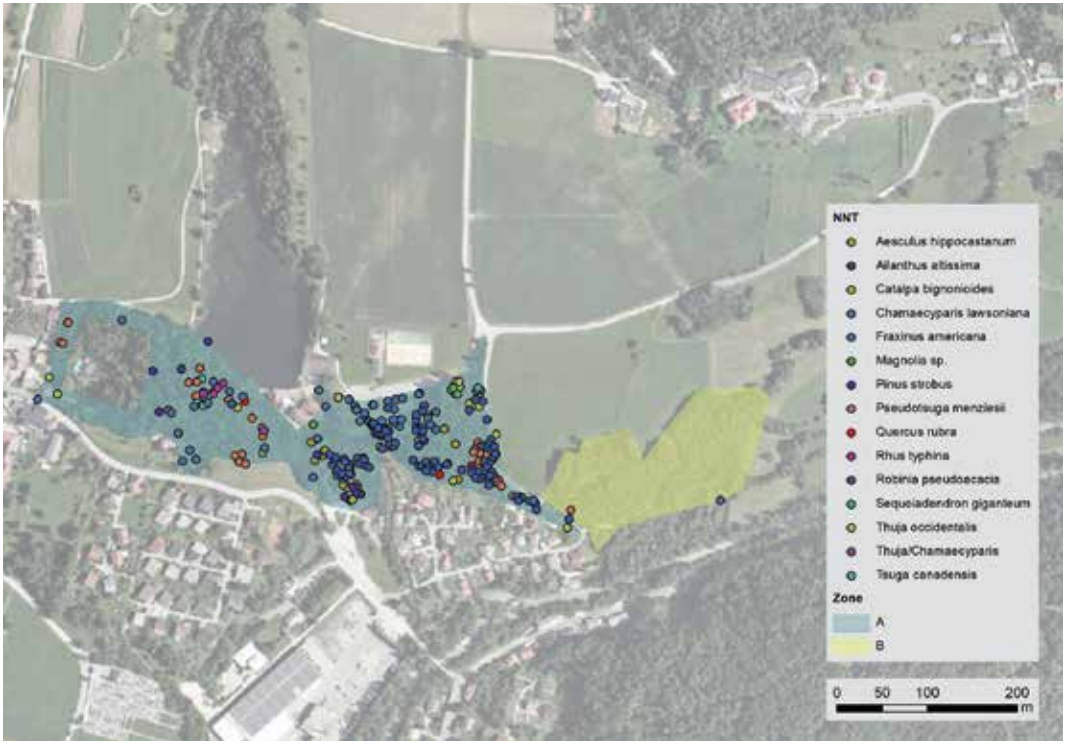

Figure 2: *Aerial photo of the study area with Zone A representing the manor's park/forest and Zone B representing a section of neighbouring managed natural forest. The coloured dots indicate the georeferenced locations of discovered NNT.*

Results and discussion

The study area was divided into Zone A (5.02 ha) representing the manor's park/forest and Zone B (2.37 ha) representing a section of managed forest (Fig. 3).

In Zone A, we discovered 16 different NNT species (Fig. 3, Table 1) with a total number of 440 individuals (Table 1). The most abundant were *Robinia pseudoacacia, Chamaecyparis lawsoniana, Ailanthus altissima, Pseudotsuga menziesii, Thuja occidentalis,* and *Aesculus hippocastanum* (Table 1). In Zone B representing the neighbouring managed natural forest that consists mainly of *Picea abies, Fagus sylvatica, Quercus petrea, Carpinus betulus, Acer pseudoplatanus,* and *Castanea sativa,* we found only two NNT, both mature trees: *Pseudotsuga menziesii* and *Chamaecyparis lawsoniana* (Fig. 3).

Natural rejuvenation of NNT

The analysis of natural rejuvenation revealed that some NNT are rejuvenating well, such as *Robinia pseudoacacia, Chamaecyparis lawsonian*a, and *Ailanthus altissima* (Fig. 3), while others are present only as mature trees (*Sequoiadendron giganteum, Magnolia* sp., *Catalpa bignonioides, Rhus typhina, Clerodendrum trichotomum*) and are not rejuvenating.

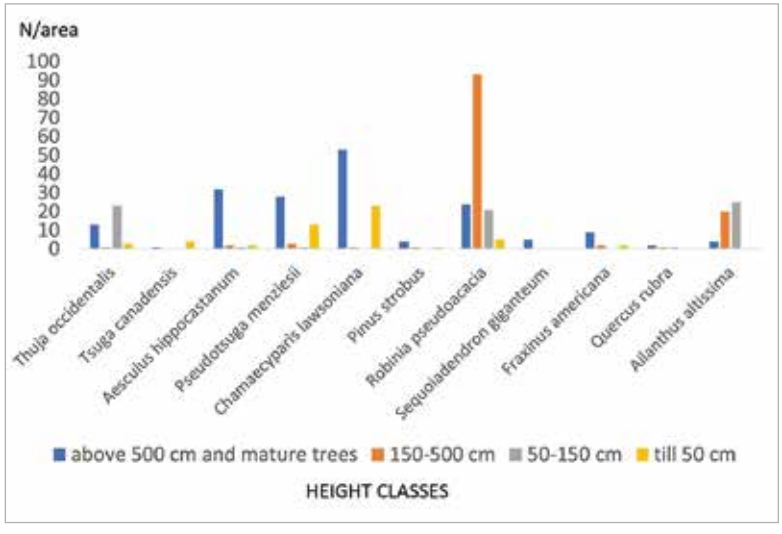

Figure 3: *Occurrence of NNT in the manor´s park/forest divided into the four height classes. Five NNT occurring only once are not represented in the graph.*

Conclusions

Our study in the Hrib Castle grounds provided four results:

1. According to the estimated age and dimensions of the present NNT, many of these trees were introduced to the manor's park more than century ago (*Chamaecyparis lawsoniana*, *Thuja occidentalis*, *Sequoiadendron giganteum*, and others in the pilot area), while some were intentionally or unintentionally introduced later (e.g., *Catalpa bignonioides*, *Magnolia* sp., *Rhus typhina*, *Clerodendrum trichotomum*).
2. Some NNT in the study area are not rejuvenating naturally (e.g., *Catalpa bignonioides*, *Clerodendrum trichotomum*) or exhibit signs of waning vitality (e.g., *Sequoiadendron giganteum*, in all probability weakened by drought stress).
3. Some NNT are rejuvenating very intensely (e.g., *Thuja occidentalis*, *Pseudotsuga menziesii*), and some exhibit signs of invasiveness in the study area (e.g., *Robinia pseudoacacia*, *Ailanthus altissima*).
4. According to a diverse set of NNT species pool in the manor's park, we would expect intense spread of NNT to the neighbouring managed forest. On the contrary, extremely few of these species have been found in the managed forest. The reason may lie in the management of this forest.

NNT - name	No.
Robinia pseudoacacia	146
Chamaecyparis lawsoniana	69
Ailanthus altissima	44
Pseudotsuga menziesii	44
Thuja occidentalis	43
Aesculus hippocastanum	37
Fraxinus americana	18
Thuja/Chamaecyparis	15
Pinus strobus	6
Sequoiadendron giganteum	5
Tsuga canadensis	5
Quercus rubra	4
Catalpa bignonioides	1
Magnolia sp.	1
Rhus typhina	1
Clerodendrum trichotomum	1
TOTAL	**440**

Table 1: *List of NNT found in the study area and their presence in numbers of individuals.*

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SELECTED NON-NATIVE TREES IN URBAN AREAS OF THE ALPINE SPACE

ABIES BORNMUELLERIANA Mattf.

Bornmüller's fir, Turkish fir

Bornmüllerjeva jelka

Bornmüllertanne, Türkische Tanne

Sapin de Bornmüller

Abete di Bornmüller

Main characteristics:

- Extremely tolerant of heat and drought – excellent silvicultural potential against the background of global warming.
- Thrives on nutrient-rich, deep, rather acidic soils in its native range.
- Outside its natural range, it is mainly planted as a Christmas tree and as an ornamental tree in parks and gardens.

Management and use in urban areas in the Alpine space

Like the Nordmann fir, Abies bornmuelleriana is mainly used for Christmas trees and as an ornamental shrub and tree in parks and large gardens. In Italy, the species is already being planted frequently along roads. The extensive crown can be a problem, but on the other hand, the deep taproot system ensures that Bornmüller's firs do not fall over easily in storms.

Tree site conditions and threats to be considered

This species prefers nutrient-rich sites and avoids groundwater-influenced soils. It occupies a similar position to the Nordmann fir (*Abies nordmanniana*) in forest communities and dominates its natural habitat due to its tolerance for shade, especially in the late stages of ecological succession. In Turkey, it is an important forest tree due to its rapid growth and comparatively high tolerance for late frost, but it has recently encountered problems with late frosts in Europe. It can withstand extreme heat and drought but does not tolerate stagnant moisture.

Invasiveness and risks

Currently considered non-invasive. However, further cultivation trials are necessary to ensure a comprehensive evaluation.

Ecosystem services provided

- Stabilizing influence in dense tree communities
- Natural sound absorber and screen along roads
- Good growth, adaptation to drought, and late bud burst in spring make it interesting with a view to climate change.

Expert recommendation

The Bornmüller's fir is to be considered non-invasive. It is not easily infested by various pests or diseases. Although it has struggled with late frosts in recent years, it is recovering better than the Douglas fir and silver fir.

ABIES CEPHALONICA Loudon

Greek fir

grška jelka

Griechische Tanne

Sapin de Céphalonie

L'abete di Cefalonia

Main characteristics:

- Occurs naturally on two Greek islands, Euboea in the Aegean Sea and Cephalonia in the Ionian Sea.
- Belongs to a group of species within the genus *Abies* presenting the earliest bud burst and the shortest elongation period.
- Emerging seedlings survive better in the relative protection of older plants.

Management and use in urban areas in the Alpine space

The Greek fir has no special soil requirements; it can even thrive on stony soils and in rock crevices and is very tolerant of drought and heat.

Although it is not particularly susceptible to fungi or diseases overall, waterlogging can often lead to fungal infestation. It is also susceptible to bark beetles when stressed by slash-and-burn or storms.

Tree site conditions and threats to be considered

Abies cephalonica is considered one of the Mediterranean fir species most sensitive to frost, suffering at temperatures below -15 °C. It is also vulnerable to fire, as it does not produce serotinous cones and thus does not maintain a canopy seed bank when summer wildfires occur. The survivability of seedlings is positively influenced by closed ground cover, higher elevation (1,600 m), shallow soil, and a closed canopy.

Invasiveness and risks

From the available literature, the Greek fir does not seem to be invasive anywhere – on the contrary, it is even considered endangered. There is a lack of data from outside its native range, however.

Ecosystem services provided

Protects sensitive Mediterranean soil from erosion. Suitable for afforestation of karst soil, and has been used for this purpose in Slovenia, Croatia, and France.

Expert recommendation

Abies cephalonica is a naturalized neophyte. It is used to reforest drought areas in the natural hybrid form A. × borisii-regis (*A. cephalonica* x *A. alba*) as well as for ornamental purposes. It is also often subjected to genetic contamination by other species of the genus *Abies*. Because of its high tolerance to heat and drought, the Greek fir should be considered a climate-smart tree, especially in times of climate change.

ACER NEGUNDO L.

Box elder

ameriški javor, negundovec

Eschen-Ahorn, Eschenahorn

erable a feuilles de frene

acero a foglie di frassino,
acero americano

Main characteristics:

- Survives well in shade and achieves high growth in full light.
- Not recommended for planting in urban areas due to its invasiveness, rapid growth, large crown, and frangible branches that can easily drop during windstorms.
- Considered problematic in many European countries.

Management and use in urban areas in the Alpine space

The box elder is used for ornamental purposes. It is viewed as a potentially aggressive agriophyte or apophyte that subspontaneously spreads into riparian habitats and abandoned lands and is therefore considered a weed. The advised countermeasure is eradication with subsequent reforestation with native species. Likewise recommended is yearly repeated girdling of adult and sapling individuals accompanied by the removal of seedlings from the understorey layer to induce the highest possible mortality.

Tree site conditions and threats to be considered

Optimal growth conditions are moist, sandy, well-permeable alluvial soils. Can tolerate low winter temperatures, but wind and snow are unsuitable conditions. The box elder can attain a competitive advantage over native species due to its excellent survivability in shade and high growth in full light. It is also able to outcompete native vegetation due to its formation of dense populations and via allelopathic effects. Water seems to be the most determining factor for its survival. Researchers advise against planting it in urban areas due to its invasiveness, rapid growth, large crown, and frangible branches that can easily drop during windstorms and cause damage to property.

Invasiveness and risks

Acer negundo is considered problematic in many European countries and currently classified as invasive throughout Southern, Central, and Eastern Europe, where it mostly occurs in riparian habitats. It is considered a pioneer species due to its adaptability and can often overgrow abandoned agricultural lands.

Ecosystem services provided

Acer negundo has little economic use, as its wood has undesirable characteristics: It is light, soft, close-grained, and of low strength. Recently, however, research has shown a potentially interesting use for the wood due to its aesthetic characteristic and unique red colouring.

Expert recommendation

With a view to arboricultural work, *Acer negundo* is very difficult to climb, since its branches are fragile and breakable. Male trees release large amounts of pollen and therefore have high allergenic potential during the flowering period. The box elder is a fast-growing and fairly short-lived tree that can reach up to 25 m in height. The shoots are green, often with a whitish to pink or violet waxy coating when young. Branches are smooth and tend to retain a fresh green colour rather than forming a bark of protective dead tissue.

ACER SACCHARINUM L.

Silver maple, creek maple

srebrni javor

Silber-Ahorn

Érable argenté

L'acero saccarino, acero argenteo

Main characteristics:

- Planted in many urban areas due to its ease of transplanting and establishment, adaptability to a wide range of sites, rapid growth, and good form.
- Has frangible branches, therefore inadvisable for planting near houses, roads, or landlines.
- Possible invasiveness potential due to its fast growth and prolific seed production.

Management and use in urban areas in the Alpine space

The silver maple was introduced to Europe in 1723 and is nowadays planted as an ornamental tree all across the continent. It is often used in urban areas because it is easy to transplant and establish as well as being adaptable to a wide range of sites; it also grows rapidly and has an appealing form. Owing to its large dimensions, it is more common in public spaces and parks, along avenues, and the like. Its branch strength is rated as weak to medium weak, the root damage potential as high. This means it is susceptible to wind and snow damage if not pruned frequently.

Tree site conditions and threats to be considered

Grows best on deep, moist, and well-drained soils, but can tolerate other soil types as well as low temperatures, drought, air pollution, and occasional floods. It is the most photophilic of all maples. Its weakness are its frangible branches, which can be dangerous during storms and strong winds or under heavy snow; planting close to houses, roads, and landlines is therefore discouraged.

Invasiveness and risks

Acer saccharinum was first reported to form invasive patches along the banks of the rivers Meuse and Ourthe in Belgium in 2008. In recent years, however, it has been naturalizing in riparian habitats in various parts of Europe, for example in France and Germany. Further naturalization, especially along rivers, is very likely in the near future. It is otherwise not classified as an invasive tree species, however.

Ecosystem services provided

Silver maple sap can be used to make a good, light syrup, although the sap's sugar content is the lowest among the maple species used for syrup.

Expert recommendation

Acer saccharinum has not been a key focus of forestry in many countries of the Alpine space (Germany, Hungary). Due to its prolific seed production and fast growth, there is possible invasiveness potential in abandoned sites (ruins, unmanaged yards, factory areas, gravel pits, etc.) and near water bodies or railway tracks. This is most problematic for riparian forests, which are often already quite fragile. Additional trials in mixture under control are recommended. On the positive side, the species is affected by very few pests and diseases and can tolerate drought and air pollution.

ACER TATARICUM L.

Tatar maple, Tatarian maple

tatarski javor

Tatarischer Steppen-Ahorn

l'Érable de Tartarie

Acero dei tartari

Main characteristics:

- Native range extending across eastern Europe and western Asia.
- Irregular canopy with slender branches; often grows as a bush.
- Very hardy and tolerant of adverse conditions.

Management and use in urban areas in the Alpine space

The Tatarian maple is reported to be native in Slovenia but can no longer be found in forests there. It is commonly planted as an ornamental tree in eastern Austria, southern Slovakia, Hungary, and throughout the Balkan Peninsula. It is considered a very important woody species and suitable for urban habitats under expected climate change conditions in Europe.

Tree site conditions and threats to be considered

Acer tataricum grows well in moist, well-drained soils rich in organic matter; prefers full sun or bright, sun-dappled locations. It has some tolerance for drought, no serious insect or disease sensitivity, and performs best in areas with cool summer climates.

Invasiveness and risks

Not classified as an invasive tree species in the European Union. The Tatarian maple has escaped cultivation and naturalized by self-seeding in certain parts of the eastern United States of America. Likewise naturalized in parts of Russia, it has spread quickly there in recent years.

Ecosystem services provided

Planted as shelterbelts in Ukraine to protect railways from snowstorms. It is also good for bees, and its fallen leaves improve the soil. Planted individually or in groups as an ornamental tree.

Expert recommendation

Acer tataricum is perhaps a somewhat underestimated species. It could be used more often as a meliorative tree for planting in degraded areas due to its resistance to summer drought, partial shade tolerance, and certain pioneer properties. It also has several other useful characteristics and is praised as a decorative species. Because of its low, often bushy form, it has hitherto not been studied intensively in forest plantations for timber production in Europe.

AESCULUS x CARNEA

Red horse-chestnut

rožnati divji kostanj

Rotblühende Rosskastanie

Marronnier à fleurs rouge

Ippocastano rosa

Main characteristics:

- Holds up well in urban areas, even in restricted and compacted soil spaces.
- No invasive potential detected.
- Has a somewhat fragile form and produces considerable amounts of litter.

Management and use in urban areas in the Alpine space

Aesculus x *carnea* is a beautiful landscape tree for parks, parking lot islands, highway median strips, and medium-wide lawns. It may also be planted as a shade tree. Depreciation of the foliage during the growing season due to diseases and insects can somewhat limit its value, however. Usually grows with several trunks and branches that droop as the tree grows, so pruning is necessary to ensure a strong structure. Too much pruning can expose the trunk bark to sun, however, causing it to crack; the trunk therefore needs to be protected by leaving lower branches on small trees and avoiding over-pruning.

Tree site conditions and threats to be considered

The red horse-chestnut prefers moist, fertile soils but is easily grown in any average, medium-moisture and well-drained soil in full sun to part shade. Once established, it can be difficult to transplant because of its deep taproot. Often not recommended as a street tree because its flowers, nuts, twigs, and leaves produce a considerable amount of litter; the large, slowly decomposing leaves in particular may be objectionable to some people in fall.

Invasiveness and risks

Not classified as invasive in Europe.

Ecosystem services provided

The flowers of the red horse-chestnut are very attractive to bees, and its nuts make good food for wildlife. Individuals of the species are also often planted for shade.

Expert recommendation

There is no data available on the invasiveness of *Aesculus* x *carnea*. Due to its genetic origin, seed germination, and reproduction strategies, however, it does not seem to have significant invasive potential. Among the benefits of the species are its good resistance to drought and the horse-chestnut leaf miner (*Cameraria ohridella*) compared to *Aesculus hippocastanum*. It is very difficult to climb, as its branches are fragile and breakable.

AILANTHUS ALTISSIMA (Mill.) Swingle

Tree of heaven

veliki pajesen

Götterbaum

ailante, arbre du ciel

Ailanto, Albero del paradiso

Main characteristics:

- Commonly found in urban areas, particularly on disturbed sites.
- Very difficult to control, especially where mechanical control measures are limited.
- Currently in the top 20 environmental weeds identified as targets of classical biological control in Europe.

Management and use in urban areas in the Alpine space

The tree of heaven has been a commonly planted ornamental tree for a long time and has been able to spread invasively into dry ruderal habitats and as a pioneer species on abandoned dry grasslands. It is problematic in urban areas due to its ability to grow in every crack. Since it is an invasive alien species of European Union concern, various techniques and measures are being employed to control it, prevent its further spread, detect new infestations, and eradicate recently detected populations. It is prohibited by law to bring *Ailanthus altissima* into the European Union, reproduce it, cultivate it, transport it, buy it, sell it, use it, exchange it, and own it.

Tree site conditions and threats to be considered

The tree of heaven can grow on poor soils and is resistant to disturbed or stressed habitats. It is also tolerant to salt, air pollution, and a broad spectrum of climatic conditions including humidity, light, and moisture levels. Young plants are sensitive to extreme cold. The pollen is a known allergen. The species has fragile wood and the branches dry quickly as it grows; it therefore requires constant care. Furthermore, all parts of the plant have a strong and distinct odour that is often likened to that of peanuts.

Invasiveness and risks

*Ailanthus altissim*a has become invasive on all continents except Antarctica. The species can have negative impacts on ecosystem services as well as negative economic impacts by affecting infrastructure. It can also have implications for human health, as contact with the leaves can cause severe dermatitis and the pollen can trigger allergic reactions. It can negatively affect native biodiversity through direct competition and through allelopathic effects.

Ecosystem services provided

The species has been used for afforestation in karst areas in the past as well as for landscaping, gardening, and construction. Some countries have used it to breed the silk moth *Samia cyntia*. It can also serve for shelterbelts and erosion control, land reclamation, medicine (roots), furniture, and oil (seeds). Due to the allelopathic compounds it produces, it may have potential for development as a natural herbicide.

Expert recommendation

The tree of heaven is an undesirable species due to its aggressive vegetative repulsion, especially by female trees, as well as due to its seeds and its unpleasant odour. Pulling is generally the best method to get rid of it. Individuals grow rapidly and can reach heights of 15 m in 25 years. Although it is a short-lived tree in any location and rarely lives more than 50 years, its suckering ability allows it to clone itself indefinitely. *Ailanthus altissima* is among the tree species most tolerant to pollution, including sulphur dioxide, which it absorbs in its leaves. It can withstand cement dust and fumes from coal tar operations as well as resisting ozone exposure relatively well. Furthermore, high concentrations of mercury have been found accumulated in its tissues. The tree of heaven's drought-tolerance is also high due to its ability to effectively store water in its root system. As a result of these characteristics, it is frequently found in areas where few trees can survive.

ALNUS CORDATA (Loisel.) Duby

TItalian alder

srčastolistna jelša

Herzblättrige Erle

L'Aulne de Corse, Aulne cordé

L'ontano napoletano

Main characteristics:

- *Alnus cordata* is native to the southern Apennine Mountains and the north-eastern mountains of Corsica.
- Forming a roughly pyramidal shape at maturity, its foliage is particularly striking due to the glossy green texture and heart-shaped (cordate) leaves.
- Unlike other alders, *Alnus cordat*a is not a riparian species.

Management and use in urban areas in the Alpine space

The Italian alder is of minor importance in Alpine space urban areas, as it is very rare. It can occur in parks and gardens or as an ornamental tree. The species prefers acidic to slightly alkaline sites with sandy-loamy to loamy soils, and performs better in dry than wet conditions. It is an extremely hardy tree.

Tree site conditions and threats to be considered

Alnus cordata grows well on moist, well-drained soils but is quite tolerant of dry and poor conditions. Its resistance to wind makes it an ideal plant for screening and windbreaks as well as for planting in coastal regions. It grows rapidly even under very unfavourable circumstances.

Invasiveness and risks

The Italian alder is not known to be invasive in its introduced range. It has naturalized in countries outside its native range, however, and it grows fast on difficult sites such as mining spoil heaps and heavily compacted urban soil.

Ecosystem services provided

Soil protection and windbreaks. In coppices, the species was traditionally used for firewood. It can also stimulate the growth of associated species due to its nitrogen-fixing root capacity and nitrogen-rich and easily degradable leaves, which improve litter and soil quality.

Expert recommendation

Symbiotic bacteria growing on the roots of *Alnus cordata* fix atmospheric nitrogen. Besides enabling the tree to grow well in poor soils, some of this nitrogen also becomes available to other plants growing nearby. Useful as a fast-growing tree on dry, difficult sites, especially with soils with higher pH levels, but can also tolerate moist, acidic soil. Alder seedlings do not grow well in shady site conditions.

BROUSSONETIA PAPYRIFERA (L.) L'Hér. ex Vent.

Paper mulberry

papirjevka murva

Papiermaulbeerbaum

Mûrier à papier

Broussonetia o gelso da carta

Main characteristics:

- A characteristic feature of this species are its large, very hairy leaves and broad, conspicuous stipules.
- So far, no specific pests and diseases affecting *Broussonetia papyrifer*a have been reported.
- Its suitability as an alternative urban tree species for climate adaptation in Europe is being tested.

Management and use in urban areas in the Alpine space

The paper mulberry is planted as an ornamental tree in Europe. It is more common in the Mediterranean region, where it can be found in parks and gardens and lining avenues. The species needs soils with a sand content of 25 %; it requires regular watering and should be fertilised with tub plant fertiliser every 2 to 3 weeks from April to October. During their first 2 to 3 years, trees should not be stored below 10 °C. The paper mulberry is rarely attacked by diseases or pests.

Tree site conditions and threats to be considered

Broussonetia papyrifera thrives in warmer habitats in urban environments and along forest edges and rivers. Light, well-drained soils and sunlit sites suit it well. It is fast-growing and short-lived, resistant to drought and late frosts, and considered easy to care for. Can cause pollen allergies.

Invasiveness and risks

In some regions of the world, the paper mulberry is classified as invasive because it exhibits dominant growth behaviour and displaces other species. It has the ability to colonize easily accessible habitats, especially in disturbed areas, invading open habitats such as forest and field margins and displacing native species through competition and shading. Once established, it displays an aggressive reproductive tendency, with associated negative impacts for wild animals that depend on native vegetation.

Ecosystem services provided

Broussonetia papyrifera is of considerable importance in the Indochinese culture, where it is used to make medicines such as laxatives or antipyretics. In addition, agents for the treatment of snake and dog bites as well bee stings can be produced. It is also considered a promising biofuel plant.

Expert recommendation

Other mulberry species already grown in Europe (*Morus alba*, *Morus nigra*) are preferable to *Broussonetia papyrifera*. They have already proved their worth in Central Europe and exhibit better growth performance, are less susceptible to late frost, and can be trimmed easily.

CATALPA BIGNONIOIDES Walter

Southern catalpa, common catalpa, cigartree

navadni cigarovec, ameriška katalpa

Gewöhnlicher Trompetenbaum

Catalpa commun

Catalpa americana

Main characteristics:

- Native to the south-eastern United States.
- An important ornamental plant providing urban greenery; especially popular because of its appealing blossoms.
- Also has very large heart-shaped leaves that create significant litter problems.

Management and use in urban areas in the Alpine space

One of the most frequently planted ornamental trees in Europe and often found in parks and gardens. Very common along avenues due to its resistance to the stresses of the urban environment. When planted as an ornamental in a yard setting, care must be taken to ensure it is not too close to a building, fence, property line, power line, or septic system. Ample space should be provided to let it reach its mature height. Litter and smell are the greatest management problems with ornamental catalpas.

Tree site conditions and threats to be considered

Optimal conditions for *Catalpa bignonioide*s are deep, rich, aerated, fresh to humid sandy loam soils. The species is a semi-heliophyte and can tolerate air pollution. Drought and wind are unsuitable conditions, and young plants are susceptible to frost. Dropped leaves litter the surroundings.

Invasiveness and risks

The southern catalpa may become weedy or invasive in some regions or habitats and can displace desirable vegetation if not properly managed. It produces a set of allelopathic chemicals that affect soil microorganisms and other plants, which can become stressed or damaged in the vicinity of catalpa foliage or rooting areas as a result. It is also known for its rapid growth rate.

Ecosystem services provided

Catalpa bignonioides is an important honey plant due to its late bloom. Various tree parts can also be used for medicinal purposes.

Expert recommendation

The species is not considered invasive in Europe, but this could be due to the fact that it has hitherto only been planted in urban environments for ornamental purposes and never introduced into natural environments intensively, repeatedly, and over a long period of time. Constant monitoring of its occurrence is therefore advised. Knowledge gaps exist in Europe regarding its great potential in beekeeping and the properties of its wood.

CATALPA OVATA G.Don

Chinese/yellow/Japanese catalpa

japonska katalpa

Kleinblütiger Trompetenbaum

Catalpa jaune

Catalpa a foglie ovate

Main characteristics:

- Native to East Asia, primarily Japan and China.
- Its blossoms are smaller than those of *Catalpa bignonioides*, and the leaves have no unpleasant smell.
- Not seriously affected by any known pests or diseases.

Management and use in urban areas in the Alpine space

The Chinese catalpa is planted as an ornamental tree in gardens and parks. After being introduced to Europe, it was mistaken for *Catalpa bungei* for a long time.

Tree site conditions and threats to be considered

Chinese catalpa trees are hardy and can survive in and adapt to most conditions, making them extremely easy to grow and care for. They tolerate dry and wet sites, alkaline and clay soil as well as road salt, but are most easily grown in average, medium to wet well-drained soils in full sun to part shade. The species enjoys moist fertile loams and tolerates seasonal flooding. It can be messy when its flowers and fruits fall, and its branches are brittle and may break in storms.

Invasiveness and risks

The Chinese catalpa has escaped gardens and naturalized in some states in the eastern United States.

Ecosystem services provided

Catalpa ovata is an important honey plant due to its late bloom, and various parts of its trees can be used for medicinal purposes. It is reported to absorb both lead and cadmium pollution from the air.

Expert recommendation

The Chinese catalpa has fragile and breakable branches and exhibits fast growth. It is used for ornamental purposes and to create shaded areas thanks to its wide, trilobate leaves. It is very long-lived, with older specimens reaching up to 8–10 m in height.

CEDRUS DEODARA (Roxb. ex D.Don) G.Don

Himalayan cedar

himalajska cedra

Himalaya-Zeder

cèdre de l'Himalaya

cedro dell'Himalaya

Main characteristics:

- First reports of the introduction of *Cedrus deodara* to Europe can be found in 1822, when seeds were brought to Britain.
- In its native range, the essential oils gathered from the resinous timber have a wide range of applications.
- *Cedrus deodara* forests are also often associated with meditation sites for ancient Indian sages.

Management and use in urban areas in the Alpine space

Compared to the two Mediterranean cedar species, the Himalayan cedar occurs less often as an ornamental tree in parks and gardens. Due to its flat rooting system, trees should be planted in sites with low wind speeds; furthermore, planting locations should offer enough space for the tree's sweeping branches. Requires a lot of light and enough warmth for optimal growth. The perfect timing for planting Himalayan cedar trees is in spring so as to allow them to establish well until winter. In general, urban trees of this species require no special treatment except during drought periods, when saplings need to be watered.

Tree site conditions and threats to be considered

Cedrus deodara has high precipitation demands and achieves optimal growth performance in regions with cool weather and annual precipitation of 1,000 to 1,900 mm. Its growth is therefore strongly determined by pre-monsoon temperatures and precipitation amounts during the summer. Extremely dry and warm weather conditions do not suit it. It greatly prefers deep, well-drained sites and has a reasonable tolerance for shade. Especially in younger stages, the seedlings can be susceptible to damage from frosts and cold winds; mature frost hardiness depends on provenance. In regions with large amounts of snowfall, Himalayan cedars trees are likely to suffer from snow breakage.

Invasiveness and risks

There is no specific data about the invasiveness of *Cedrus deodara*. Considering its high precipitation demands and relatively low frost hardiness, this tree species likely has little potential for invasiveness in the Alpine space.

Ecosystem services provided

The wood of the Himalayan cedar possesses good curative properties, which are well documented in Indian Ayurvedic medicine. Its essential oils are often used to repel insects. The wood is also said to have an anti-fungal effect and is therefore often used in the construction of food storage rooms.

Expert recommendation

Cedar species are generally considered to be resistant and uncomplicated. *Cedrus deodara* is one of the most frost-hardy cedars, with young plants in particular exhibiting robustness and excellent growth. The species needs plenty of light, thrives in poor and nutrient-poor soils. In view of climate change, it therefore has considerable potential for urban and forestry use.

CEDRUS LIBANI A. Rich.

Lebanon cedar

libanonska cedra

Libanon-Zeder

Cèdre du Liban

Cedro del Libano

Main characteristics:

- Exhibits low competitiveness and it is therefore often restricted in natural environments.
- Trees are sensitive when planted in moist or compacted soils.
- *Cedrus libani* is of symbolic importance in Lebanon and is depicted on the country's flag.

Management and use in urban areas in the Alpine space

The Lebanon cedar is widely used for ornamental purposes. Due to its horizontally spreading branches, it is only suitable for solitary placement in large, open gardens and parks. On public grounds, regular tree inspection is obligatory, and appropriate tree maintenance must be performed. The species prefers calcareous soils and sunny sites that are protected from wind. Due to its excellent heat tolerance, it is best suited for southward- and westward-facing slopes. Has problems with late frost.

Tree site conditions and threats to be considered

Optimal conditions for the Lebanon cedar are on limestone parent rock. It tolerates drought well but is less resistant to extreme climate changes than the Atlas cedar. A slow-growing heliophyte, it requires a lot of warmth for lignification. The species is unsuitable for environments with dense soil, polluted air, wet snow, or winter temperatures below -16 °C, which can lead to cold stress and increased mortality. According to the current state of knowledge, Cedrus libani is recommended for shallow locations on limestone, with provenances from Lebanon to be avoided owing to their susceptibility to late frost.

Invasiveness and risks

There are no reports of invasiveness as yet. Due to its rare occurrence in Central Europe, little is hitherto known concerning invasiveness, but *Cedrus libani* can be assumed to have no invasive potential due to its low competitive strength.

Ecosystem services provided

Essential oils extracted from Lebanon cedar wood are used in perfumery and microscopy (immersion oil).

Expert recommendation

Varieties of Cedrus libani are used in gardens. It is very tolerant to drought, but caution is required as it is sensitive to frost. In the Alpine space, there is particular concern when the species is planted in locations with heavy snowfall due to the possibility of breakage of its wide-reaching horizontal branches. The pollen causes moderate allergic reactions.

CHAMAECYPARIS LAWSONIANA (A. Murray bis) Parl.

Lawson cypress

Lawsonova pacipresa

Lawsons Scheinzypresse

Cyprès de Lawson

Cipresso di Lawson

Main characteristics:

- The tallest specimen of this species is from Oregon, USA and measures 66.7 m.
- Prefers medium-textured soils with consistent summer moisture.
- No reports of invasiveness.

Management and use in urban areas in the Alpine space

The Lawson cypress is a widely used species for ornamental purposes in parks and cemeteries. It is established but not common in Germany, Slovenia, and France. Cultivation and origin experiments are underway in Austria and Germany. More than 200 ornamental varieties exist. On public grounds, regular tree inspection is obligatory, and appropriate tree maintenance must be performed.

Tree site conditions and threats to be considered

Chamaecyparis lawsoniana is relatively shade-tolerant and can cope with a wide range of conditions and soil types. It tolerates moderate drought as well as air pollution and is resistant to low temperatures. Experimental sites in Brandenburg, Germany report that regeneration works very well under shelter.

Invasiveness and risks

No reports on invasiveness found.

Ecosystem services provided

Essential oil is extracted from the leaves and young stems. It has antimycotic and antibacterial properties and is used in perfumery and aromatherapy.

Expert recommendation

The Lawson cypress is affected by only few pests but is sensitive to drought. It can be planted instead of *Cupressus sempervirens*, especially in cold sites. This species can grow to impressive heights and releases a lot of pollen; it therefore has high allergenic potential during its flowering period.

CORYLUS COLURNA L.

Turkish hazel

turška leska

Baumhasel

Noisetier de Byzance

Nocciola

Main characteristics:

- Introduced to Central Europe around 1600.
- Can grow in various site conditions and is a very common tree in urban areas all over Europe.
- Its heavy fruits are eaten by wild animals and humans.

Management and use in urban areas in the Alpine space

The Turkish hazel is very popular as an ornamental tree in parks and gardens. As a result of its dense foliage, it is often planted to prevent noise and provide shade. It is resistant to summer droughts and very unsensitive to emissions, making it suitable for planting along streets or in protective plantations close to industrial areas. It is sensitive to road salt, however. In their early years, trees might not have well-established root systems; saplings therefore need to be watered intensively for half an hour once or twice a week during dry summers.

Tree site conditions and threats to be considered

The adaptability of the Turkish hazel is excellent, which makes it viable on various sites. It occurs on deep, nutrient-rich, wet to dry forest soils and alluvial soils, but also on poor soils with high volumes of debris and on stony sites endangered by erosion. It can survive extreme temperatures for short times without being damaged, and is able to develop a taproot reaching down 3–4 m, which allows it to settle even on very stony grounds. On good soils, it has a high tolerance for shade. The only conditions in which the Turkish hazel struggles are extremely dry or very wet sites as well as locations with very high salinity.

Invasiveness and risks

Due to its very low competitive strength, *Corylus colurna* is not expected to be invasive, as corroborated by experiences from numerous long-term plantations in Europe. No negative consequences for native flora, fauna, and soil have been determined so far.

Ecosystem services provided

The nuts are eaten by animals and collected by humans for consumptions or selling to confectioners. There is also the possibility of producing oil from the seeds, which is then processed by the pharmaceutical industry or used to make oil paints. Thanks to its intensive rooting, the Turkish hazel is an ideal tree species for erosion protection.

Expert recommendation

*Corylus colurn*a is very attractive for use in urban areas, which is why it is commonly found in parks and along streets. The species is very resistant to summer droughts and does not suffer from late frost events but is sensitive to road salt. It is very well-formed and self-prunes relatively well. It can be used as mixed with other species in the stand and should be planted in squads, groups, or hoards to extend the current spectrum of tree species and scatter the risk of cultivation.

CUPRESSUS SEMPERVIRENS L.

Italian cypress, Mediterranean cypress

vednozelena cipresa

Echte Zypresse, Mittelmeerzypresse

Cypres commun, Cypres vert

Cipresso comune

Main characteristics:

- Very drought-tolerant species that performs well in hot conditions.
- Needles and crown parts are flame-resistant.
- Represents a symbol of eternal life and is therefore often found near cemeteries.

Management and use in urban areas in the Alpine space

In Central Europe, the columnar form of the Mediterranean cypress, *Cupressus sempervirens* var. *sempervirens*, is the variety most commonly planted in parks, gardens, cemeteries, and as wind protection along roads. Due to its good resistance to heat and drought, cultivation in regions strongly affected by climate change could increase over the coming years. The species is considered highly adaptable and exhibits good growth even in dry and nutrient-poor soils.

Tree site conditions and threats to be considered

The Mediterranean cypress thrives in medium to deep moist and permeable soils with at least moderate nutrient supply. It needs enough light and can grow in almost all alkaline or slightly acidic soils, but should not be grown in clayey or water-saturated soils. It develops a large, shallow root system. The species' natural habitats are dominated by dry and hot summers and mild rainy winters with a precipitation rate of only 200 mm per year. Studies have shown that the needles and crown parts are flame resistant.

Invasiveness and risks

Cupressus sempervirens is planted only for its aesthetic qualities. The distribution of other tree species is not affected, and it does not endanger the ecosystem. Although it can easily regenerate in forests, it has not been reported as invasive so far.

Ecosystem services provided

The Mediterranean cypress is a popular ornamental shrub and is suitable for use in border hedges and for shading gardens. It also serves as a windbreak along roads and coasts since it can tolerate salty winds. In addition, it is widely used for various traditional medicine purposes.

Expert recommendation

Suggested for planting in urban environments, but only in small areas and mainly for ornamental purposes. In view of the expected climate changes, it is expected that this species will thrive in the Mediterranean region as it can withstand drought, mild frost, and neglect while being highly decorative. Prolonged periods of drought in summer, which are predicted for the entire region of south-eastern Europe, could have a positive effect on the use of this tree species in future. Its ornamental use generates significant economic value.

FRAXINUS PENNSYLVANICA Marshall

Green ash

pensilvanski jesen

Rotesche

Frêne rouge

Frassino della Pensilvania

Main characteristics:

- Commonly used in parks and along roads.
- Deciduous tree with a wide natural distribution in North America.
- Short-lived, with a maximum age of 125 to 150 years.
- Irregular trunks can be found in Europe, whereas they are typically straight in the native range.
- Cultivated in Europe since 1783.

Management and use in urban areas in the Alpine space

Its resilience to frost and its high tolerance to salt make the green ash suitable even for urban areas with continental climates. The species also has a low potential for ozone formation through volatile organic compounds (VOCs) and does not suffer from pollution. It can be a good alternative to common ash trees (*Fraxinus excelsior*) in the urban environment, as it is less susceptible to ash dieback disease and provides a decorative autumn colouring. The male cultivar "Summit" is particularly recommended for urban plantations as a result of good experiences concerning its heat resistance in southern France and the fact that it does not exhibit any invasive potential. Fraxinus pennsylvanica has a high resilience to accidental injuries like pruning, major root removal, or trunk damage during roadwork, even if the trees suffer multiple injuries.

Tree site conditions and threats to be considered

The growth of the green ash can differ greatly depending on site conditions. While the species generally has a wide physiological amplitude, better growth rates have been determined on soils well supplied with water and nutrients. The ideal site conditions for *Fraxinus pennsylvanica* are heavy and wet locations with long-lasting flooding events covering up to 40 percent of the vegetation period, where native tree species cannot compete with it. Late frosts can cause problems. There is no evidence that the green ash has negative impacts on soil conditions.

Invasiveness and risks

A research study in an urban forest of Bremen in Germany showed that the "Summit" cultivar is not very competitive outside of riparian forests. It was discovered to successfully regenerate over two generations in the urban forest in Bremen while showing no signs of invasiveness due to a lack of disturbances.

Ecosystem services provided

Green ash trees attract many species of birds, bats, and squirrels. They possess a good ability to recover after cutting or breaking. Researchers have investigated the ecosystem services provided by the species in cities, calculating that each green ash tree supply services worth 402 US$ per year. Recently, however, *Fraxinus pennsylvanica* has been found to be susceptible to serious disease caused by the pathogenic fungus *Hymenoscyphus fraxineus*.

Expert recommendation

Fraxinus pennsylvanica is very suitable as a road-lining tree and as a substitute for Fraxinus excelsior thanks to its good stem form and resistance to ash dieback disease. Unfortunately, the species has very strong invasive potential overall, which is why the male cultivar "Summit" is recommended. This variety has successfully passed all tests as a street tree in Bavaria without exhibiting any problems relating to site conditions. Other positive aspects are its beautiful colouring in autumn and the fact that European citizens do not recognise the green ash as "non-native".

GINKGO BILOBA L.

Ginkgo, kew tree

ginko, dvokrpi ginko

Entenfussbaum, Ginkgo, Ginkgobaum

arbre à noix, arbre à pattes de canard, arbre aux pagodese

ginco

Main characteristics:

- Native to China, Japan, and Korea.
- Living fossil providing an immense source of bioactive compounds and medicinal ingredients.
- Can reach an age of more than 2,500 years.
- Introduced to Europe in the 18th century.

Management and use in urban areas in the Alpine space

Since 1730, the ginkgo has been widely cultivated as an ornamental tree in streets and parks and as a medicinal plant, especially in China, Korea, France, Germany, and the United States. With a view to climate change, a European study assessed the species as very suitable for urban habitats in terms of its drought tolerance and as suitable in terms of its winter hardiness. This living fossil adapts well to urban conditions, and its use to line city thoroughfares has become fashionable among the parks and gardens departments of many European and American municipalities. Because the seeds of the female trees give off an odour of butyric acid, most of the planted trees are male. Since 1982, ginkgo trees have been cultivated on a large scale in France for the production of EGb extract from their leaves.

Tree site conditions and threats to be considered

While it grows best when planted in full sun, *Ginkgo biloba* has the ability to persist indefinitely under low light and low nutrient conditions, such as along the streets of densely populated cities. In cultivation, it tolerates a wide variety of seasonal climates ranging from Mediterranean to cold temperate, where winter temperature minimums can reach -20 °C. Although frequently described as slow-growing, it can exhibit growth rates of up to 30 cm per year for the first 30 years or so of its life. There is little literature on pests or diseases affecting the ginkgo, as it is very resistant to them.

Invasiveness and risks

There are no reports of invasive potential of this species.

Ecosystem services provided

The medicinal parts of the ginkgo tree are its fresh or dried leaves along with the seeds after separation from their fleshy outer layer. It is valuable for aesthetic reasons as well, especially in autumn when its leaves turn yellow.

Expert recommendation

A combination of resilience to diseases, insect-resistant wood, and the ability to form aerial roots and sprouts makes the ginkgo a long-lived species, with some specimens reported to be more than 2,500 years old. It is known to be a strong emitter of biogenic volatile organic compounds (BVOCs). The juice from the fruits can cause skin irritation.

GLEDITSIA TRIACANTHOS L.

Honey locust

Ameriška gledičija, trnata gledičevka

Amerikanische Gleditschie

févier d'Amérique

spino di Giuda

Main characteristics:

- Native to North America.
- Grows a tap root that makes it a stable tree species under windy conditions.
- The wood is very heavy and dense at 700 to 800 kg/m^3.

Management and use in urban areas in the Alpine space

Among the various varieties of the honey locust used as ornamental trees in parks and gardens and as windbreaks in dry areas, the cultivars without thorns are planted preferentially for obvious reasons. Generally, the species offers perfect characteristics for planting as hedges or wind protection. After trimming, strong resprouting creates thorny and impassable hedges. When used for windbreaks, *Gleditsia triacanthos* has an average annual height growth of about 50 cm in the first seven years. Provenances from the northern areas of its natural distribution range tend to exhibit higher frost tolerance, while trees from the southern parts grow fruits with higher nutrient content. Most honey locust trees that can be bought in Europe are provenances with lower rates of fruit production. Due to its good frost hardiness and resistance to drought and high temperatures, Gleditsia triacanthos is a good choice for planting along streets or parks in urban areas.

Tree site conditions and threats to be considered

The honey locust performs well on shallow soils and is resistant to drought and high salinity. It can grow on alkaline as well as on acidic soils, and a low nitrogen supply constitutes no problem for the species as well. It achieves its best growth performance on wet, nutrient-rich soils with a pH value between 6 and 8. In combination with its high tolerance for flooding, this means that *Gleditsia triacanthos* is ideal for use in bottomlands.

Invasiveness and risks

Especially in the southern hemisphere, the honey locust is a strongly invasive tree species. In Europe, it is currently rated as potentially invasive, with only few cases of invasion documented as yet. For the future, the role of *Gleditsia triacanthos* as an invasive tree species is expected to become more pronounced, as changing climatic conditions will promote its regeneration and growth.

Ecosystem services provided

The honey locust provides a source of pollen and nectar during its relatively short blooming period. It is planted as protection against erosion and wind or as an ornamental tree in cities. In its native range, its fruits serve as food for cattle, goats, wild animals, squirrels, rabbits, corvids, and starlings.

Expert recommendation

There are numerous tree species suitable for compensating the loss of certain native species due to climate change. Therefore, the importance of *Gleditsia triacanthos* is rather low. Nevertheless, the species may represent an interesting option for silviculture due to its drought tolerance and resistance to pests and browsing by game. It is already being used in urban areas because of its insensitivity to drought, salinity, and cutting, as well as due to its importance as a food supply for bees. Negative aspects worth mentioning are its irregular crown form, fruit fall, deadwood, and development of thorns. No honey locust individuals are to be found outside of cities, and its invasive potential is therefore currently low. In areas becoming drier due to climate change, however, the species may pose a problem in future, and countermeasures may become necessary. Since *Gleditsia triacanthos* is known to have a high demand for light, one possible management measure could be the promotion of other tree species that can outgrow and dominate it.

JUGLANS NIGRA L.

Black walnut

črni oreh

Schwarznuss

noyer noir

noce nero americano

Main characteristics:

- Native to the eastern and midwestern USA.
- Introduced to Europe for ornamental purposes in the early 17th century.
- Nowadays, it is cultivated on a larger scale for timber production.

Management and use in urban areas in the Alpine space

The black walnut has high ornamental value and is frequently used in parks and gardens in European cities. In some parts of Europe, it has also been used for the rehabilitation/restoration of degraded land, for example in low-productive black locust stands in Moldova or former quarries in Croatia. *Juglans nigra* has very specific soil demands: It does not tolerate acidic soils nor strong compaction. It also requires light and warmth. No pests and hardly any dangerous fungi are known. Should not be pruned during the leaf growth period.

Tree site conditions and threats to be considered

Optimal growing conditions for the black walnut are deep, rich, loose and moist soils in lowlands, preferably in river valleys. It cannot grow on heavy clay soils or in habitats prone to long flooding events but can tolerate moderate drought and temperatures down to -30 °C. Frost can nevertheless damage young trees. *Juglans nigra* is a heliophyte that prefers warm and mild climates with frequent and well-spread precipitation. Globally speaking, it is the best-known allelopathic species due to the substance juglone present in all parts of the trees.

Invasiveness and risks

The species is not considered invasive.

Ecosystem services provided

Black walnut seeds are an important product for animals and humans. The species is used in agroforestry due to the high value of its wood, its nut production, and the characteristics of its foliage, which allows the penetration of sufficient light to support plant growth in the understory. Suitable for rehabilitation/restoration of degraded lands. The green fruit shell (the husk) is well-known as a natural colorant.

Expert recommendation

This species is currently considered non-invasive.

Expert opinion

Fruit fall may cause issues on paved surfaces during autumn. Black walnut trees release a lot of pollen and therefore have high allergenic potential during the flowering period. Most parts of the tree including the leaves, stems, and fruit husks have a very characteristic pungent or spicy odour. This odour is absent in the nut itself, however. *Juglans nigra* is more resistant to frost than the English or Persian walnut. It can cause laminitis in horses when present in their bedding. The species is of particular interest with regard to future weather extremes – especially heat and drought, to which it is well suited.

KOELREUTERIA PANICULATA Laxm.

Golden rain tree, pride of India

latnati mehurnik

Blasenesche, (rispiger) Blasenbaum

Arbre a vernis de Chine,
Koelreuteria paniculee
La koelreuteria, albero delle lanterne cinesi

Main characteristics:

- Native to China, Korea, and Japan.
- Popular as an ornamental tree in Europe.
- In Europe, it is found in riparian forests, ruderal sites, and urban habitats.
- All parts of the tree are poisonous, including the seeds, pods, flowers, buds, leaves, petals, wood, bark, and roots.

Management and use in urban areas in the Alpine space

The golden rain tree is very popular as an ornamental tree because of the yellow blossoms it produces in autumn. It can be planted individually or in groups, as well as along roads. Its blossoms are used in medicine; their extract also provides a yellow dye, while the leaf extract provides a black dye. The species tolerates the urban environment, air pollution, and high temperatures well.

Tree site conditions and threats to be considered

It is a modest species that prefers deep, fertile, well-drained soils and can grow on acidic or alkaline soils. Needs warm and sunny sites and tolerates moderate drought. Younger trees are sensitive to low temperature. Wind does not harm *Koelreuteria paniculata*, but it cannot grow in seaside areas.

Invasiveness and risks

The golden rain tree is reported as invasive in North America, especially in Florida. In Slovenia, the species rarely grows in the wild so far, but it is already spreading throughout cities in some European countries.

Ecosystem services provided

A valuable ornamental tree for parks. The blossoms of the golden rain tree are used for medicinal purposes such as treating inflamed eyes. Its leaves and blossoms are used to produce black and yellow dye respectively, while the seeds are often used to make rosaries. It is also a honey tree.

Expert recommendation

Koelreuteria paniculata is a naturalized neophyte, and a plant that requires no special care or pruning. It is resistant to most pests but susceptible to root rot if the soil is not well drained, and it can suffer from branch canker that causes knobby growths. The seeds are irritating, and poisonous.

LARIX KAEMPFERI (Lamb.) Carrière

Japanese larch

japonski macesen

Japanische Lärche

mélèze du Japon

arice giappone

Main characteristics:

- Planted as an ornamental tree as well as in forest plantations.
- Provides high-quality wood.
- Grows faster than *Larix decidua* and is also more resistant to larch canker.

Management and use in urban areas in the Alpine space

In Slovenia, the Japanese larch is planted as an ornamental tree in parks and gardens, and only rarely in forest plantations. It was introduced to Europe in the 18th century and has been actively used in gardens, forests, and parks since 1861. There are many varieties of *Larix kaempferi* used in gardening that differ in size, crown shape, and needle characteristics. A relatively low-maintenance tree, it will tolerate pruning but usually looks best without. Deer do not particularly care for it and will usually leave it alone in favour of tastier options. Has no significant negative characteristics.

Tree site conditions and threats to be considered

In Europe, the oceanic climate is most suitable for the Japanese larch. Wet, heavy snow causes damage to it. For good growth, it requires air and soil moisture and a longer vegetation period compared to the European larch. Resistant to wind and air pollution.

Invasiveness and risks

There are no reports on invasiveness of this species.

Ecosystem services provided

Flavonoids present in Japanese larch wood act as strong feeding deterrents to the subterranean termite, *Coptotermes formosanus* Shiraki, while the *arabinogalactan* from the wood exhibits a feeding preference effect, indicating that the water extracts from the wood may potentially be useful in termite control as a deterrent or an attractant. One study indicates that the biogenic volatile organic compounds (BVOCs) of *Larix kaempferi* have therapeutic potential for the treatment or prevention of local and systemic inflammation due to their immuno-suppressive effects.

Expert recommendation

The Japanese larch tolerates pruning well and can also be used as a hedge tree. It is similar to *Larix decidua*, but has purple-red winter shoots covered with waxy fluff. Its wood is very elastic and can assume very unusual shapes.

LIQUIDAMBAR STYRACIFLUA L.

American sweetgum

ameriški ambrovec

Amerikanischer Amberbaum

Copalme d'Amérique

Storace americano

Main characteristics:

- Occurs naturally in the eastern and south-eastern parts of North America.
- Introduced to Europe in 1680.
- In Europe, it is mainly used for ornamental purposes.
- Its wood is of average quality, flexible, and very fragrant.

Management and use in urban areas in the Alpine space

Because of its striking autumn colours, the American sweetgum's most important role is as an ornamental tree. It is a very popular tree in parks and along streets. It does well in most urban conditions and is relatively disease-free and resistant to most insect pests. The species requires a lot of light and prefers stony, compacted soils. In the first few years after being planted, it needs to be protected from competing flora. Browsing by game can also be a problem.

Tree site conditions and threats to be considered

Liquidambar styraciflua grows best on moderately coarse to fine soils that are well drained and slightly acidic (pH 6.1–6.5). It develops a deep taproot with numerous highly developed laterals on well-drained bottomland sites and a shallow, widely spreading root system on poorly drained sites. It is very intolerant to shade but can withstand flooding and can grow in seaside sites if protected from high winds. Young trees on wet ground are frequently damaged by frost. Does not grow well on dry sites. The species is susceptible to iron chlorosis on high-pH soils, frost damage to late summer shoot growth, occasional bleeding necrosis, leader dieback, sweetgum blight, leaf spots, the sweetgum webworm, caterpillars, cottony-cushion scale, sweetgum scale, and walnut scale.

Invasiveness and risks

There are no reports of invasiveness so far, but the species can easily resprout from roots.

Ecosystem services provided

The American sweetgum's seeds are eaten by birds, squirrels, and chipmunks. It is a good choice as a windbreak tree because of its fast growth and tolerance for a wide variety of sites. Frequently used as a specimen plant, shade tree, and street tree. The leaves and bark are used to obtain a resin commonly known as liquid amber, which is added to chewing gum as well as being used in the medicine and perfume industries.

Expert recommendation

Fruit litter can cause problems on paved surfaces. *Liquidambar styraciflua* releases a lot of pollen and therefore has high allergenic potential during its flowering period. It is also known to be a strong emitter of biogenic volatile organic compounds (BVOCs), and its seeds may be a renewable source of shikimic acid. The species is of particular interest with regard to future weather extremes and climate change, as it is particularly heat-tolerant and drought-resistant and can withstand heavy flooding for up to 20 days without any problems. It also tolerates industrial and vehicular exhaust fumes well.

LIRIODENDRON TULIPIFERA L.

Tuliptree

navadni tulipanovec

Tulpenbaum

Tulipier de Virginie

L'albero dei tulipani

Main characteristics:

- Has large tulip-like flowers.
- Native to North America.
- In Europe, it has been cultivated for a long time and can be found in parks, public gardens, and experimental plots.

Management and use in urban areas in the Alpine space

The tuliptree has limited suitability in urban areas, as it requires a lot of space and develops an extensive root system. It is less suitable along roads than in large parks and public gardens. Studies have shown that although the species is winter-hardy, it must be classified as problematic in terms of its drought tolerance. *Liriodendron tulipifera* has been cultivated in Europe since 1663 and is often found in urban gardens and parks as well as in experimental plots of forest research institutions.

Tree site conditions and threats to be considered

There are several vigorous tuliptree populations in the two federal states Baden-Württemberg and North Rhine-Westphalia (Germany). The species grows in riverside forests and on lower mountain forest sites up to around 500 m on weakly acidic to moderately basic medium to deep substrates. *Liriodendron tulipifera* is very well suited as a mixed tree species for oak, beech, and maple stands, as well as for transitioning pure stands from natural regeneration into mixed stands and for filling even small gaps. Abiotic stresses such as late frost, soil compaction, snow breakage and snow pressure can affect it.

Invasiveness and risks

The tuliptree has hitherto not been classified as invasive, and its potential for invasiveness is considered low. According to previous experience, integration into natural, indigenous forest communities is possible without problems. However, further observation is required.

Ecosystem services provided

Liriodendron tulipifera enriches the biodiversity and aesthetic value of forests, gardens, and parks. Its flowers and seeds are important food sources for many insects, birds, and small mammals. The leaf litter is easily degradable and improves the humus in the topsoil, thus ensuring nutrient enrichment of the soil. All parts of the plant, especially its wood and bark, are toxic to humans.

Expert recommendation

The tuliptree has great potential for forestry use in Central Europe as it exhibits very good growth behaviour and is non-invasive. There are several experimental plots in Germany (Esslingen, Freiburg), Austria (Graz), and Belgium, and the species is now also being reproduced in Europe. It tolerates dry periods but is very susceptible to late frost. Young plants in particular need to be protected from late frost and game browsing following afforestation of exposed areas. Natural reproduction is problematic, as 70% of the seeds are infertile. *Liriodendron tulipifera* thrives best in loose stands with sufficient light and medium nutrient supply. The species should be introduced sporadically, as nest planting can lead to pest infestation. No specific diseases are known, but caterpillars do occasionally infest it. The wood is easy to work and suitable for the furniture industry as well as for interior finishing and insulation, as it is very large-pored. The tuliptree's suitability for urban areas is limited, since it forms an extensive root system and does not tolerate compressed soil. It can grow well in large parks and gardens, however.

MAGNOLIA GRANDIFLORA L.

Southern magnolia, evergreen magnolia

velecvetna magnolija

Immergrüne Magnolie

Magnolia a grandes fleurs

Magnolia sempreverde

Main characteristics:

- The only evergreen magnolia species.
- More than 100 different cultivars and 2 varieties of *Magnolia grandiflora* exist.
- Native to North America.

Management and use in urban areas in the Alpine space

Use of the southern magnolia is only recommended in locations with warm summers and very mild winters, and its suitability for planting in the Alpine region is therefore limited. On unsuitable sites, the species cannot develop its full potential: Its vitality and aesthetics are reduced, and the intensity of required care and the failure rate increase. For urban locations in south-eastern Europe, however, it represents a promising alternative.

Tree site conditions and threats to be considered

Magnolia grandiflora can tolerate short periods of late frost and sub-zero temperatures without problems if the basic climate is appropriate. It thrives best in climatically mild areas of Great Britain, the Mediterranean, and south of the Alps in general, but variants exhibiting good growth in the northern part of the Alps exist as well. In Central Europe, continuous watering is necessary.

Invasiveness and risks

There is no invasiveness information available.

Ecosystem services provided

Magnolia grandiflora is a popular tree for its aesthetics along streets, in the centre of cities, and in Mediterranean and exotic parks and gardens. It is a "state tree" in the U.S. states of Louisiana and Mississippi. Certain parts of the plant can be used for therapeutic purposes; the native American Choctaw and Koasati, for example, use the bark as medicine. Its evergreen leaves are used in floristry to make bouquets, and magnolia seeds are a food source for birds and small mammals. In the south of Great Britain, the southern magnolia is used as an espalier tree on stately mansions.

Expert recommendation

Magnolia grandiflora is gaining popularity in urban areas in Germany and Austria. The trees are ideal for greening cities because of their high aesthetic value and resistance to heat and drought. Even colder temperatures and late frost are unproblematic as long as the basic climate is suitable. As it is an evergreen species, it also pollutes pavement areas less than related species. Precipitation in the southern magnolia's native range is almost twice as high as in Central Europe, so the species depends on a continuous watering regimen when planted here, making it unattractive for forestry use. *Magnolia grandiflora* is non-invasive, and specific diseases have not yet been discovered, although trees tend to develop mildew in rainy summers. Snails can infest young plants. The choice of a suitable provenance is a decisive factor for the establishment of the southern magnolia, and it would therefore be desirable to research and develop variants of the species over the coming years that are better adapted to different locations. With regard to expected climatic changes, *Magnolia grandiflora* is a species with excellent characteristics for distribution in Europe.

MAGNOLIA x SOULANGEANA

Saucer magnolia

Soulangeeva magnolija

Tulpen-Magnolie

Magnolia de Soulange

Magnolia di Soulange

Main characteristics:

- One of the most popular ornamental trees of the genus *Magnolia*.
- Often planted in gardens and urban parks due to its attractive tulip-like pink flowers.
- Named after Étienne Soulange-Bodin, a French botanist who created it by crossing two species of magnolia from Asia.
- Thrives in sunny, wind-protected, and nutrient-rich locations but is sensitive to drought and heat.

Management and use in urban areas in the Alpine space

The saucer magnolia is a common ornamental plant in gardens, parks, and urban areas. It is most commonly planted solitarily due to the outstanding ornamental features it displays throughout the year. Magnolias are considered sensitive to drought and heat, which is why they possess only limited suitability for greening urban areas. In Central Europe, the species mainly grows in a form of an ornamental shrub.

Tree site conditions and threats to be considered

Magnolia x *soulangeana* thrives best as a solitary tree in deep, moist, humus-rich and slightly acidic soils. It requires sunny, wind-protected locations with good nutrient supply and is tolerant to ozone. Vulnerable to late frost as it blooms before the leaves shoot. Although considered a resilient species, infestation by *Pseudomonas syringae*, *Siphoninus phillyreae*, and mildew is possible.

Invasiveness and risks

As it is planted exclusively as an ornamental plant, *Magnolia* x *soulangeana* does not affect ecosystems and other species. It is generally considered non-invasive.

Ecosystem services provided

Magnolias are important cultural trees in Asia. Bark extracts for medicinal purposes are produced from some species. In Europe, *Magnolia* x *soulangeana* has hitherto mainly appeared as an ornamental plant. It increases biodiversity and contributes to increasing the aesthetic value of urban green spaces.

Expert recommendation

The species is known to be a strong emitter of biogenic volatile organic compounds (BVOCs).

PAULOWNIA TOMENTOSA (Thunb.) Steud.

Princess tree

pavlovnija

Kaiser-Paulownie

Paulownia

Paulownia

Main characteristics:

- Fast-growing tree reaching up to 18 m in height, with large and distinctive heart-shaped leaves.
- Introduced to Europe from China as an ornamental plant at the beginning of the 19th century.
- Valued for its high-quality wood used in furniture, decorative products, and musical instruments.
- Potentially invasive species in Europe.

Management and use in urban areas in the Alpine space

Princess trees were originally planted as ornamentals, and the species' current distribution throughout Europe is almost exclusively confined to urban areas and parks. In the Alpine space, occurrences have been recorded in Germany (naturalized), Austria, Switzerland, France, Slovenia, and Italy. In several countries, natural regeneration has also been observed. It is predominantly present in urban areas and industrial wastelands as well as along railways, mainly due to the generally relatively warm temperatures in cities. Also common on roadsides, clearings, forest margins, cliffs, steep rocky slopes, riverbanks, and in disturbed habitats. Can occasionally be found near gardens or in pavement cracks as well.

Tree site conditions and threats to be considered

Extraordinarily resistant to stress factors such as extremely high summer temperatures and periods of drought in urban areas. Thrives in deep, moist and well-drained aerated soil, sheltered from the wind and with sufficient sunlight. Fallen fruits and large leaves can constitute a litter problem in cities, and the species can also form large surface roots that can affect nearby road infrastructure. The princess tree produces thousands of seeds that readily germinate in spring and may become a nuisance in gardens as well as in gaps and cracks in pavements and driveways. The seeds require light for germination, and *Paulownia tomentosa* therefore often grows in disturbed habitats. Once removed, all roots should be eliminated as well to prevent regrowth and further spreading. Does not tolerate early or late frosts, which lead to leaf loss. The minimum temperature for the princess tree is 15 °C. In its first years, intensive nursery care and extensive irrigation is necessary. From the 5th year onwards, it can tolerate drought and is superior to native tree species in this respect. To prevent ecological risks, the princess tree should not be cultivated on a larger scale or near open habitats of high conservation value.

Invasiveness and risks

Paulownia tomentosa has a tendency to escape and invade, growing rapidly in disturbed areas. It seeds profusely and resprouts from roots and stumps, eventually forming monocultures. As a pioneer species, it predominantly establishes in open sites. Planted ornamental trees can represent sources of seed dispersal to surrounding urban green and natural habitats. The seeds are dispersed up to 3.5 km from mature plants by water and wind and remain viable for a long time. Besides distribution by seeds, the princess tree can also reproduce vegetatively via regrowth from root or stem material. It may eventually prove invasive in Europe. It should be monitored closely in the future, as it could potentially colonize near-natural habitats, especially under predicted climate change conditions.

Ecosystem services provided

In some European countries, the princess tree is cultivated as an ornamental due to its beautiful flowers. It is found in botanical gardens, arboreta, and parks. Also sometimes used for windbreaks along roads and on farmlands and canal banks in the Mediterranean. The species is also believed to reduce sulphur dioxide pollution and could act as a particularly good sink for carbon dioxide due to its large leaf area. Young trees can be a source of food for wild mammals, as the leaves are tasty and very rich in protein.

Expert recommendation

The potential invasiveness of the hybrids grown in plantations (mostly "Shang-Tong") can be reduced by cutting off all inflorescences. This removal is very costly, however, and will likely not prove sufficient to prevent the species' spread due to its vegetative propagation, which can be suspected for hybrids as well. In Germany, princess tree seedlings are affected by game browsing, but not by other pests or diseases.

PICEA OMORIKA (Pančić) Purk.

Serbian spruce

omorika, Pančićeva smreka

Serbische Fichte

Epicea de Serbie

Abete rosso della Serbia

Main characteristics:

- Narrow-crowned, slender, and elegant coniferous tree species.
- Aesthetically pleasing and tolerant to city pollution, therefore suitable for planting in urban areas.
- Natural range nowadays limited to a small area in the central Balkans, on the border between Serbia and Bosnia and Herzegovina.

Management and use in urban areas in the Alpine space

The Serbian spruce is often used for urban greening in cities due to its tolerance to urban pollution and its aesthetic qualities. It can be planted individually or in groups, and also as an evergreen street tree serving as a screen. Owing to its low water and nutrient requirements, it is also often used in gardens. An extremely hardy species, it prefers sunny to semi-shady sites that are stony and pH-neutral (with a pH of around 7) and offer a moderate nutrient supply. The soil should also be loose, as the Serbian spruce does not tolerate waterlogging. It is best planted in autumn and generally easy to care for, requiring no pruning and only some additional watering in hot summers. In larger plantations, omorika death (needle browning) often occurs due to magnesium deficiency and chlorine enrichment. *Armillaria*, red rot, bark beetles, and the Sitka spruce aphid can also cause problems.

Tree site conditions and threats to be considered

Picea omorika is very tolerant of urban conditions. It requires an average annual temperature of 4–6 °C and total precipitation of around 1,000 mm. It exhibits slightly slower growth compared to *Picea abies* but is very resistant to biotic and abiotic damage. Pruning is required only for vehicular or pedestrian clearance beneath the canopy in urban areas, and surface roots are usually not a problem.

Invasiveness and risks

This species is considered non-invasive..

Ecosystem services provided

Used for the production of Christmas trees and decorative brushwood.

Expert recommendation

The Serbian spruce regenerates quite well after catastrophic fire events. As it is adapted to growing in cold climates, however, the current climate change predictions may lead to survival problems. Regeneration is difficult due to more competitive herb and other plant species. For these reasons, *Picea omorika* is classified as an endangered species in the IUCN list. Its wood was valued for its good quality in the past and used to make special kinds of pots for cheese. Where a better wood is not available, the timber can be used primarily for roof construction.

PICEA PUNGENS Engelm.

Colorado spruce, blue spruce

bodeča smreka

Blaufichte, Stechfichte

Épicéa du Colorado

abete del Colorado, picea pungentee

Main characteristics:

- Subalpine species native to the Rocky Mountains of Colorado and Utah (USA).
- Coniferous tree with blue-green needles and a pyramidal crown with horizontal branches.
- Planted and cultivated as an ornamental tree in urban areas.

Management and use in urban areas in the Alpine space

The blue spruce is a subalpine species native to the Rocky Mountains of Colorado and Utah (USA) that has been widely introduced to many other regions. In the Alpine space, it occurs exclusively as an ornamental tree in urban parks and gardens, where it is commonly planted solitarily or as a screen and rarely exceeds heights of 15 m. Its foliage is blue or blue-green, and many cultivars of the species are known. *Picea pungens* needs plenty of sun and dry soils, ideally sandy or gravelly loamy soils that are nutrient-rich and alkaline. It is very easy to care for and requires no special treatment other than a wide planting hole to allow the roots to spread well. However, it is very susceptible to fungi such as *Chrysomyxa*, *Armillaria*, or pine fire rot, and the Sitka spruce aphid is also often a problem.

Tree site conditions and threats to be considered

Due to their relatively shallow root system, it is not recommended to plant blue spruces close to buildings and roads. Trees will also require pruning for vehicular or pedestrian clearance beneath the canopy in urban areas. The species thrives in cool, deep, well-drained soil. It requires light to sunny half-shade without too much direct sun, as it does not tolerate warm and dry climates and tends to dry out in hot weather. It must also be sheltered from the wind, although blue spruce is decidedly windfirm. It casts dense shade when branched to the ground, allowing no undergrowth or grass to grow beneath it.

Invasiveness and risks

Likely carries no serious risk of invasiveness, as it is not known to be a pioneer species.

Ecosystem services provided

The blue spruce provides ornamental value in green urban areas, landscaping, and gardening. Due to its stiff, horizontal branches and blue foliage, it lends a formal air to any landscape. The species supports wildlife – most notably squirrels, which like its resin – and provides erosion control thanks to its root system. It can also be used as a medicinal plant (infusions of the needles) and is grown for the Christmas tree industry.

Expert recommendation

If not pruned, blue spruces can potentially become very large. The species is tolerant to warm microclimates and therefore a better choice than *Picea abies* for many urban sites. It is attacked by two species of *Adelges*, aphid-like insects that cause galls to form. Moreover, it is susceptible to several needle casting diseases that cause the needles to turn yellow, mottled, or brown before falling off.

PICEA SITCHENSIS (Bong.) Carr.

Sitka spruce

sitka

Sitka-Fichte

Épinette de Sitka

Il peccio di Sitka

Main characteristics:

- Native to North America, where is naturally distributed in coastal areas with high precipitation and mild temperatures.
- Introduced to Europe in the 18th century.
- Very important commercial tree in some European countries.

Management and use in urban areas in the Alpine space

The Sitka spruce exhibits strong reproduction potential in areas with beneficial soil and climatic conditions (high precipitation and mild temperatures). It should therefore not be planted in such regions to limit its invasiveness potential. Outside of these areas, it can be used in cities without restrictions, as the continental climate does not promote unintentional spreading. However, the species' low drought resistance makes it unattractive for planting in Central and Eastern European cities.

Tree site conditions and threats to be considered

Picea sitchensis prefers deep and nutritious soils allowing rooting depths of up to 2 m. Sites with compacted soil in the upper ground level and waterlogging should be avoided, as these conditions contribute to creating very flat rooting systems and an accordingly high risk of windthrow. It is somewhat suitable for planting along streets, as it tolerates salt well but is not very resistant to air pollution and drought. Even when exposed to weak concentrations of air pollutants, the Sitka spruce begins to struggle. The risk of importing potentially emerging pathogens to Europe from North America with Sitka spruce seedlings should be considered as well, as forestry in some regions relies on the species' suitability.

Invasiveness and risks

The Sitka spruce is not considered invasive in most European countries and generally does not present any danger for natural ecosystems. Invasiveness is only an issue in a very small area of the coastal heathlands of Norway with specific climatic conditions. There, the species has changed the microclimatic conditions and forest floor species composition, threatening a landscape of high conservation value. It has therefore been blacklisted in Norway since 2012 as a precaution. In Ireland, where it has already been used for silvicultural purposes for a long time and dominates 60 percent of all plantations, it is not considered invasive.

Ecosystem services provided

Picea sitchensis can provide a habitat for birds, especially for nesting and roosting. Snags and live trees with broken tops provide nesting spots for primary and secondary cavity nesters. It also can be used for medicinal purposes (for example, tea can be made from the young shoots).

Expert recommendation

Although mostly used for forestry, the Sitka spruce can make an attractive ornamental when given sufficient space to develop. If planted in appropriate conditions, it readily establishes and displays fast growth. It is light and easy to work with, and its good strength-to-weight ratio makes it suitable for fencing, pallets, and general construction.

PINUS STROBUS L.

Eastern white pine, Weymouth pine

gladki bor, zeleni bor

Weymouth-Kiefer, Strobe

Pin Weymouth, pin du lord, pin blanc

Pino strobo, pino di Lord Weymouth

Main characteristics:

- Very tall coniferous tree native to North America.
- Has three-sided needles in fascicles of five and cylindric grey-brown seed cones 8–20 cm long.
- One of the most important economic species and of great interest for forestry, but also planted as an ornamental tree in parks and gardens.
- Widely planted in Europe, then abandoned during the 20th century due to blister rust.

Management and use in urban areas in the Alpine space

The Weymouth pine is a North American species first introduced to Europe in 1705 and subsequently widely planted and distributed across the continent during the 19th century. It has also frequently been planted for ornamental purposes in urban areas, as well as in private and public gardens. Due to infestation by the blister rust *Cronartium ribicola*, the species was eventually completely abandoned in forestry. *Pinus strobus* has a wide ecological range, growing in regions with harsh and mild winters and at elevations from sea level up to 2,200 m depending on climatic conditions. The upper altitudinal limit in Switzerland is estimated to be around 800 to 1,000 m above sea level.

Tree site conditions and threats to be considered

The Weymouth pine grows on nearly all soil types. It is most competitive on fairly infertile sandy soils such as well-drained outwash soils and occurs only scarcely on clayey or poorly-drained soils. It is moderately shade-tolerant and requires a good water supply and enough summer heat. Its soil and nutrient demands are very low, and it can withstand a wide range of temperatures, humidity, and water regimes, though it prefers well-drained soils and cool, humid climates. Its rather weak wood makes the species susceptible to breakage. The lower branches are retained during tree growth, making it aesthetically suitable for planting as a single tree or in groups. Susceptible to salt injury from roads and sensitive to air pollution. White pine blister rust (*Cronartium ribicola*) can affect planted trees.

Invasiveness and risks

Pinus strobus is considered an invasive species in the Czech Republic, Germany, and Hungary as well as other countries. Although it was previously planted on a large scale, records of invasions are not abundant. At present, in the Czech Republic, the long-lived species is highly invasive in several mainly sandstone areas but non-invasive in other parts. It is now a component not only of planted mixed forests but also of other forests, as well as occurring in sparsely vegetated rocky sites. In Central Europe, many sandstone areas are protected as unique environments, and large-scale regeneration of an alien tree species therefore constitutes a serious conservation concern. Weymouth pine seeds can disperse up to 750 m from the source.

Ecosystem services provided

The Weymouth pine provides food (seeds, foliage, bark) and a habitat for numerous wildlife species, including nesting opportunities for birds. It is also used as a Christmas tree.

Expert recommendation

Pinus strobus seed cones ripen in the summer of their second year after pollination and tend to be dropped after the seeds have been released. The species is low-maintenance and grows rapidly as a specimen tree. If not pruned, individuals can potentially become very large, but with regular shearing they can also be trained as hedges. Some cultivars are even used in bonsai. The Weymouth pine is also well-suited for people with allergies and is moderately fire resistant: Mature trees survive most surface fires due to their thick bark, branch-free trunks, and moderately deep rooting habits. Furthermore, the needles have a relatively low resin content and are therefore not particularly flammable. Younger trees are not as fire resistant, but mature survivors are able to re-seed burned areas. The white pine weevil (*Pissodes strobi*) and white pine blister rust (*Cronartium ribicola*), an introduced fungus, can damage or kill *Pinus strobus* trees. Not recommended as a street tree due to its widespread, moderately deep roots.

PINUS WALLICHIANA A.B. Jacks.

Bhutan Pine, Himalayan white pine

Himalajski bor

Tranenkiefer

pin de l'Himalaya

pino dell'Imalaia

Main characteristics:

- Native to the Himalayan region of Asia from Afghanistan to Myanmar.
- 12- to 18-cm-long blue-grey needles in fascicles of five.
- Introduced to England in 1823.
- Fast-growing tree mostly used as an ornamental.

Management and use in urban areas in the Alpine space

The Himalayan pine is widely used as an ornamental plant and appreciated in cities for its relatively high resistance to air pollution, which it tolerates better than some other conifers. In Europe, it is planted in parks and large gardens for its attractive foliage and large, decorative cones.

Tree site conditions and threats to be considered

Suitable for light (sandy), medium (loamy), and heavy (clay) soils; prefers well-drained soil and can grow in heavy clay and nutrient-poor soils. Accepts pH levels from acidic to neutral. The Himalayan pine can survive on exposed sites, but it looks much better when grown in sheltered locations. It can tolerate strong winds but not maritime exposure, and cannot grow in the shade. It is unsuitable for agroforestry because the needles contain terpene, which is released when rain washes over them and it has a negative effect on the germination of some plants, including wheat. Old trees retain their lower branches.

Invasiveness and risks

No invasiveness has been reported in Europe, and the potential seems low as this species grows in cool, deep soil and is resistant to the cold, prefers a humid climate and sheltered sites, and will not tolerate drought and heat. It should be surveyed in sheltered locations, but it is easy to control as it does not reproduce vegetatively.

Ecosystem services provided

Pinus wallichiana provides cultural ecosystem services as an ornamental tree in Europe, where it is valued for its attractive foliage and decorative cones. It is used in urban greening, landscaping, and gardening. It also provides erosion control due to its pivoting root system and can be used as a commercial source of turpentine and tar. The turpentine obtained from the resin of all pine trees is antiseptic, diuretic, rubefacient, and vermifuge.

Expert recommendation

It is difficult to assess what benefits this species could offer in comparison to the existing Alpine pine species, which are likely more drought resistant. Due to its origins, *Pinus wallichiana* has a reasonable degree of resistance to cold, but it is susceptible to late frost. It is not recommended as a street tree because it has widespread, moderately deep roots.

PLATANUS ACERIFOLIA (Aiton) Willd.

London plane

javorolistna platana

Ahornblättrige Platane, Bastardplatane, Gewöhnliche Platane

platane, platane commun

platano, platano commune

Main characteristics:

- Deciduous tree growing up to 40 m in height with widely spreading branches, maple-like leaves, flaky bark, and spiky round clusters of fruits.
- Popular street tree all over the world, widely cultivated since the late 1600s.
- First discovered in London in 1663 as a hybrid between *Platanus orientalis* and *Platanus occidentalis*

Management and use in urban areas in the Alpine space

The London plane is a very common tree in parks and gardens and along roads. It is strongly recommended as a street plant for urban areas, especially because of its tolerance to air pollution. It is also more resistant to common diseases and pests and more cold-hardy than the American sycamore. Artificial light affects its leaf fall phenology, with trees exposed to higher levels of light maintaining green leaves longer into autumn and winter. Irrigation of planted London planes through summer and autumn during years with below-average rainfall is recommended, as it reduces the potential for progressive xylem cavitation and facilitates leaf onset in spring.

Tree site conditions and threats to be considered

Platanus acerifolia can withstand the high pH, pollution, and dirt of cities. It can handle heavy pruning and is frequently pollarded. It is also able to withstand drought, smoke, and other unfavourable soil and atmosphere conditions better than many other trees. The species' high drought tolerance is confirmed by the fact that London planes show no significant decline in growth during drought years. With a view to climate change, however, *Platanus* species are likely to be more affected by summer and autumn droughts and heat waves in the future. Several pests and diseases can cause problems in planted trees.

Invasiveness and risks

Not classified as invasive in Europe.

Ecosystem services provided

Platanus acerifolia is valued for providing excellent shade. Studies show that a London plane planted on the western side of a house can reduce carbon emissions from summertime electricity use by an average of 31% over 100 years. Suitable for phytoremediation purposes and reforestation of land after mining.

Expert recommendation

In the urban environment, the London plane is one of the most common tree species in Europe, as it shows excellent resistance to harsh urban conditions. The species is extremely annoying to prune, however, since the tiny hairs on its leaves and young twigs can cause respiratory irritation. Use of facial masks and pruning in winter (but not at sub-zero temperatures) is therefore recommended for the sake of arborists' health. *Corythucha ciliata*, the sycamore lace bug, is a problem for both people and objects nearby (e.g., cars parked under the canopy). Massaria disease caused by the fungus *Splanchnonema platani* has a strong influence on the decision whether or not to plant plane trees in cities, as it entails the danger of branch breakage and subsequent injury to tree climbers attaching their ropes to infected branches. *Platanus acerifolia* provides good shade, but anthracnose (*Apiognomonia veneta*) can thin its canopy. It tolerates damage to the root system well, but branches tend to break in wet storms due to the large leaf surface and resulting weight of water.

POPULUS × CANADENSIS Moench

Canadian poplar

kanadski topol

Kanadische Pappel

Peuplier du canada

pioppo canadese

Main characteristics:

- Hybrid obtained by crossing *Populus nigra* (Alpine area) and *Populus deltoides* (North America).
- Most of these hybrid clones were developed in northern Italy by the Istituto Casale Monferrato beginning in the 1930s.
- The most famous clones are I-214, Dvina, and Neva.

Management and use in urban areas in the Alpine space

The Canadian poplar is a hybrid species primarily developed to provide wood. It is cultivated all over the temperate world, and in the meantime also used to green urban areas due to its tolerance for paving and frost resistance. It is suitable for lining streets as well as for theme parks, coastal areas, and windbreaks. Mainly cultivated in plains and very rarely found at higher altitudes.

Tree site conditions and threats to be considered

Populus x *canadensis* needs deep soils (at least 50 cm deep) with good water supply. It can adapt to various climatic conditions but is easily stressed by drought. Poplars have very extensive and aggressive root system, which may cause damage to pavement and other structures in urban sites, particularly in the case of waterproof floor coverings. Their fast growth allowing them to quickly reach heights of around 30 m can also sometimes be problematic in the vicinity of buildings. The female plant produces fruits during spring which can cause discomfort for city inhabitants and problems for climate air filtration systems, as well as being a nuisance for vegetable crops in peri-urban or urban areas.

Invasiveness and risks

Not considered an invasive species. Nevertheless, it can cross spontaneously (albeit rarely) with *Populus nigra*, the black poplar. In this case, a risk of introgression may occur due to the genetic proximity to *Populus nigra*. Poplar seeds are embedded in significant quantities of pappus (i.e. long, white, silky hairs attached to the seed) to promote wind dispersal over great distances. Poplars are prolific seed producers and typically they produce large quantities of airborne seeds in the spring. That is why the female individuals of these poplar hybrids are particularly dangerous when planted close to airports as well to hospitals and wherever the air should be maintained clean. Therefore, their seeds can create unsafe conditions along airports, or their seeds can interfere with the cleaning air systems and create malfunctioning of them. Male flowers can sometimes trigger pollen allergies in humans.

Ecosystem services provided

Erosion control (due to the strong and tangled root system), CO_2 sequestration, lumber production, and water purification and phyto-remediation thanks to the capabilities of the microflora harboured by the Canadian poplar's root system (heavy metals, brownfields, along agricultural fields)

Expert recommendation

Many cultivars are sensitive to bacteria, viruses, leaf rust diseases, and cankers. *Populus* x *canadensis* is also known to be a strong emitter of biogenic volatile organic compounds (BVOCs). It is often difficult to distinguish from *Populus nigra*, which has more rounded young twigs, a wedge-shaped (or sometimes truncated) leaf base, and no glands at the point of insertion of the stalk with the lamina.

PRUNUS CERASIFERA L.

Cherry plum

mirobalana

Kirschpflaume

Myrobolan ou Prunier-cerise

mirabolano

Main characteristics:

- Popular ornamental tree for garden and landscaping use.
- Often planted for its very early bloom (mid-February).
- Native to western Asia and the Caucasus.

Management and use in urban areas in the Alpine space

The cherry plum is a popular ornamental tree for garden and landscaping use thanks to its very early bloom. Numerous cultivars have been developed, including several with attractive purple foliage. In case of invasive behaviour, the species cannot be controlled by simply cutting trees down, as they can resprout from trunks and roots.

Tree site conditions and threats to be considered

As a small-statured tree, the cherry plum is suitable for urban areas where space is limited. It prefers well-drained, deep and sufficiently moist soils and is not suited to compacted soil. Its optimum growth performance is achieved in full sun, though it can tolerate some shade. It is uncertain whether the cherry plum can adapt well to climate change, especially to summer droughts. Susceptible to a large number of insect and fungal pests and frequently damaged by deer browsing.

Invasiveness and risks

So far, *Prunus cerasifera* has not been identified as invasive in Europe, but it has escaped cultivation on some sites and is frequently found near towns and along roadsides as well as in chaparral, woodlands, and riparian areas. Naturalized in parts of south-eastern Australia, where it is considered a mildly invasive weed in bushlands near urban centres. Although they may be competitive to some native trees and shrubs, cherry plum trees generally grow quite sparsely and thus have a limited impact compared to species forming dense patches.

Ecosystem services provided

Cultivated cherry plums can feature fruits, foliage, and flowers with multiple different colours. Some varieties have sweet fruits that can be eaten fresh, while others are sour and better for making jam. The species is also used as a rootstock for different types of grafted plum trees such as greengage, quetsche, or mirabelle plum.

Expert recommendation

Continued use as an ornamental tree is possible, but *Prunus cerasifera* is not interesting for use in Alpine forests. Can enrich some urban ecosystems as it is not invasive, but has little capacity to adapt to climate change. Existing Mediterranean small fruit trees should be preferred in multifunctional forests.

PRUNUS SEROTINA Ehrh.

Black cherry

pozna čremsa

Amerikanische Traubenkirsche

capulin

ciliegio nero

Main characteristics:

- Among the first American tree species to be cultivated as ornamentals in European gardens.
- Its leaves emerge in late spring and fall from the tree just before winter.
- Controlling its invasive spread demands huge efforts.

Management and use in urban areas in the Alpine space

In Europe, the black cherry is often planted as an ornamental tree in cities due to its beautiful flowers, coloured leaves, quick growth, and good tolerance to pruning. Trees can be pruned and maintained at shrub size by cutting them to the ground every 2 to 3 years. The species is also common in urban areas and parks, particularly in less intensively managed situations, and is sometimes planted in hedgerows as well. Due to its invasiveness in many parts of Europe, it is proposed for inclusion on the list of Union concern. Control measures were adopted as soon as the species began to spread rapidly outside plantations, but these efforts have largely proven unsuccessful.

Tree site conditions and threats to be considered

As a fast-growing species, *Prunus serotina* is suitable for urban areas. It has a high demand for light but can grow on nutrient-poor as well as dry soils. Does not grow well on soils with high pH levels, however. Not recommended for planting close to walks and pavement, as soil compaction decreases its capacity for root system development and consequently its drought resistance. Can tolerate relatively low winter temperatures.

Invasiveness and risks

The black cherry is able to disperse into the landscape very easily. Urban habitats are susceptible to invasion by the species, particularly the edges of urban forests or the interiors of forests with relatively open canopies. As a pioneer species, it benefits from anthropogenic disturbances such as forest management and soil disturbance, which make sites more favourable for seedling establishment and recruitment from the soil seed bank. Eradication efforts are costly and demand frequent monitoring. Though generally a moderately long-lived tree, the fact that the black cherry is prone to storm damage needs to be considered in urban environments. Its bark, roots, and leaves contain concentrations of toxic cyanogenic compounds.

Ecosystem services provided

As a fruit-bearing tree, *Prunus serotin*a is an important wildlife food source – particularly for birds, which also contribute to long-distance dispersal of its seeds. The fruits are edible but not particularly tasty to humans and are therefore most often used for beverages. The bark of the branches has medicinal effects. In its native and introduced range, the black cherry is used to enrich biodiversity and ameliorate soil conditions. As it can quickly become an aggressive colonizer, however, it may contribute to decreasing biodiversity.

Expert recommendation

In several parts of Europe, *Prunus serotina* is one of the most common invasive alien tree species. There are different approaches to this problem: Many countries try to combat the species, removing it and attempting to limit its spread, which is rarely successful. At the same time, there is little research on (nor evidence of) its potential harmfulness to natural environments or human health. In fact, most of the negative attitude towards the black cherry seems simply due to the fact that it is an alien species. The second possible approach, which is already being applied in some parts of Europe, is more pragmatic. Since the species produces high-quality wood and its fruits promote biodiversity and the animal component of forest ecosystems, and because it has no proven serious negative impacts on the environment, it is considered a useful tree species wherever it has spread and integrated into the natural tree composition. However, there is currently little comprehensive research on the black cherry and its potential in Europe, and it would make sense to accelerate knowledge generation on the species. Since it is difficult to eradicate and can resprout from stumps, its complete elimination from invaded areas is very costly. Considering the latter approach wherever possible therefore seems sensible.

PRUNUS SERRULATA Lindl.

Japanese cherry

japonska češnja

Japanische Blütenkirsche

Cerisier a fleurs

Ciliegio del Giappone

Main characteristics:

- Widely used as an ornamental tree in urban areas.
- Has more than 120 cultivars.
- The cultivar "Kanzan" is famous for its attractive bloom in spring.

Management and use in urban areas in the Alpine space

The Japanese cherry is common as an ornamental tree along roads, parking spaces, walking paths, or in other urban green spaces. It requires regular maintenance in urban areas due to its susceptibility to diseases such as the fungus Monilia laxa; common measures like pruning after infection are necessary. The frequency of planting of the species in urban areas is expected to decrease in future, as it is not resistant to drought.

Tree site conditions and threats to be considered

Prunus serrulata can potentially grow in a variety of different climatic conditions and is considered resistant to air pollution in urban areas. It needs good drainage but can grow on clay soils as well as on slopes or in raised beds. Highly acidic to slightly alkaline soils are preferred. Planting on wet sites with waterlogging should be avoided due to its susceptibility to fungal diseases.

Invasiveness and risks

There is no indication of potential invasion risks in the Alpine space or in Europe in general.

Ecosystem services provided

The Japanese cherry is appreciated as an ornamental urban tree because of its decorative visual appearance, with individuals or groups of trees sometimes representing major touristic attractions. However, the species is not considered pollinator-friendly, as it produces only little nectar for insects.

Expert recommendation

Prunus serrulata is a suitable species for ornamental planting along pathways and cycle paths but is not considered to be resistant to future climatic conditions.

PSEUDOTSUGA MENZIESII (Mirb.) Franco

Douglas fir

navadna ameriška duglazija

Douglasie

Douglas bleu

Abete di Douglas

- **Main characteristics:**
- Evergreen species with a pyramidal crown.
- Mature trees are characterized by reddish-brown bark with deep, thick grooves.
- Should be planted in full sun to partial shade on acidic, well-drained loamy soil.

Management and use in urban areas in the Alpine space

Based on the available literature, the Douglas fir appears to be primarily used as a forest tree rather than an urban tree. Due to its characteristics, however, it might also play an important role in urban forestry to improve climate resilience in cities with extreme environmental conditions such as drought and higher temperatures. Further studies on the benefits of using this species in urban areas in the Alpine space should be conducted.

Tree site conditions and threats to be considered

Pseudotsuga menziesii should be planted in full sun to partial shade on acidic, well-drained loamy soils. Young trees have a spired pyramidal shape and are easy to transplant, but are not yet tolerant of drought conditions. Mature trees achieve large dimensions, and sufficient growing space should thus be provided.

Invasiveness and risks

In urban areas, the Douglas fir does not exhibit invasive behaviour, and no major risks are associated with the species.

Ecosystem services provided

The Douglas fir is valued for its high growth potential and the technical properties of its wood. It is usually cultivated to produce saw timber, while wood fibre use is less common. In several regions across the Alpine space, the species is an important timber tree due to the strength of its wood, which is hard and resistant to abrasion. It dries rapidly with little movement and is relatively easy to work with. Douglas fir wood primarily serves for building and construction but is used for a wide variety of other wood products as well (e.g., flooring, furniture, cabinets).

Expert recommendation

Pseudotsuga menziesii is valued for its considerable carbon sequestration ability, providing the highest fixation content among the temperate conifers. The carbon storage period is extended when the wood is harvested in forests and processed into wood products or used for construction. Douglas fir wood is also used as an energy source and thus serves as a substitute for fossil fuels. Douglas firs have similar properties to other native conifers in terms of ecology and aesthetic value. However, experiences from forest plantations show that the species has more flexible branches and its crowns are less susceptible to physical damage compared to some native conifers. It therefore may also be suitable for increased use as an ornamental tree in urban areas.

QUERCUS COCCINEA Münchh.

Scarlet oak

škrlatni hrast

Scharlach-Eiche

Chêne écarlate

Quercia della cocciniglia,
Quercia scarlatta d'America

Main characteristics:

- Mainly native to the central and eastern United States.
- The name refers to the autumn colouration of its foliage.
- Can be mistaken for the pin oak, the black oak, or the red oak.

Management and use in urban areas in the Alpine space

The scarlet oak is sometimes planted as an ornamental tree due to the spectacular bright red foliage it displays in autumn. Its shade-casting ability is also much appreciated in city centres. Since it is a large tree, it should be planted in locations offering sufficient space for it to grow upward and spread to its mature size.

Tree site conditions and threats to be considered

A light-demanding species that occurs on dry, sandy, usually acidic soils and grows best in deep, nutrient-rich soil. In urban areas, it does not tolerate salinity or shade. Even though it prefers dry edaphic conditions, its drought and fire tolerances are only average. The most harmful disease, especially for seedlings, is powdery mildew or oak white (*Microsphaera quercina*).

Invasiveness and risks

Quercus coccinea is closely related to the northern red oak (*Quercus rubra*). It can therefore be expected to be equally invasive as the latter, or perhaps even more. Since it tolerates drier ecological conditions in terms of soil and air, it could replace native oak species.

Ecosystem services provided

The scarlet oak is a commercially very important tree species since it is an important source of hardwood timber. The wood has very large pores and is resistant to decay. It is suitable for joinery and veneer and is easy to work and split but difficult to plane. Impregnation is required for exterior uses.

Expert recommendation

This species seems interesting for planting in parks. However, it is advised to be placed sufficiently far from native forests to prevent potential invasive spreading. Its drought tolerance is at least partly derived from its ability to root deeply, so it will not exhibit as much drought hardiness where its rooting depth is constrained. The cultivar "Splendens" has won the Royal Horticultural Society's Award of Garden Merit.

QUERCUS RUBRA L.

Northern red oak

rdeči hrast

Rot-Eiche

Chêne rouge d'Amérique

Quercia rossa

Main characteristics:

- Tolerant of urban conditions and often planted as an ornamental tree.
- Large crowns display attractive colouring in autumn.
- Grows best in deep, fertile soil.
- Longevity greater than 150 years, branch strength rated as strong.

Management and use in urban areas in the Alpine space

Little is known about urban use of the northern red oak in the Alpine space or other parts of Europe, though it has been planted as a street tree. Dendrochronological studies in urban areas indicate a strong climatic growth dependence and high winter hardiness for northern red oak trees in urban areas. Compared to native *Quercus* species, *Quercus rubra* shows significantly better water use efficiency during drought season, which indicates a more economical use of water compared to native species. It is also considered quite resistant to drought in urban areas and thus might be an important candidate for adaptation to climate change in cities in the Alpine space.

Tree site conditions and threats to be considered

Can grow in full sun to partial shade. The northern red oak needs rich and well-drained soils with clayey, loamy, or sandy texture. Acidic to slightly alkaline soils are optimal. Its seaside tolerance is good in mild climates as well. Trees of the species emit large amounts of biogenic volatile organic compounds (BVOCs), and their pollen is a severe allergen. Susceptible to aphids, caterpillars, insect galls, and various fungal diseases like *Armillaria*, *Anthracnose*, *Phytophthora*, root rot, and rust.

Invasiveness and risks

Like in forest ecosystems, the northern red oak tends to naturalize in urban areas. Individual street trees or trees in parks are not considered to have such tendencies, but they can provide a sufficient source of seeds to populate nearby urban areas. The risks associated with its invasive potential are high – particularly in urban forests, where *Quercus rubra* can pose a serious threat to the native biodiversity of various organism groups (e.g., plants, fungi, soil microbes).

Ecosystem services provided

The northern red oak is considered an attractive species and is used as an ornamental tree in cities. It produces acorns, a desirable food for birds and squirrels, and serves as a source of biomass. From an ecological perspective, particularly with regard to climate change, mixing northern red oaks into urban forests is thought to increase the resilience of their ecosystems to changes in the disturbance regime, thus helping to maintain basic ecosystem functions.

Expert recommendation

Citizens are familiar with the tree species because it is often cultivated as a street tree and consequently not perceived as exotic compared to other non-native tree species. With its red autumn leaves and frequent and abundant yield, it is usually viewed rather positively. On the other side, its strong and almost stratified rejuvenation is mostly perceived negatively, since it leads to changes in species composition and an overall decline of species richness of the ground vegetation.

QUERCUS SUBER L.

Cork oak

hrast plutovec

Korkeiche

Chêne liège

Querce dasughero

Main characteristics:

- Characterized by its thick bark used for a wide variety of products.
- The bark is an adaptation to hot and dry conditions and protects trees from fires.
- Cork oak savannas are very diverse landscapes with high conservation and aesthetic value.

Management and use in urban areas in the Alpine space

The cork oak is currently not used in urban areas within the Alpine space. However, it is considered suitable for urban parks and residential areas due to its interesting bark and historical associations. It could also be planted as a street tree in conjunction with faster-growing species. In the Mediterranean regions of France, it is used in forest stands for commercial cork production.

Tree site conditions and threats to be considered

As a short-stemmed and wide-spreading tree, *Quercus suber* requires ample growing space and sufficient soil volume. Long-living and slow-growing, the species is characterized by low tolerance to shade and high drought resistance, and could thus be particularly suitable for drier and hotter sites in city centres. Its acorns are attractive to animals and may be a nuisance in pedestrian areas, but they are produced only infrequently. The evergreen leaves and relatively good shade-casting ability may be a problem in wintertime. Requires an oceanic climate.

Invasiveness and risks

The cork oak is not considered an invasive tree species. Many of its traits – like its low dispersal capacity owed to the large, heavy fruits – do not suggest a high risk of invasiveness. Some reports indicate that it is naturalizing in the Balearic and Canary Islands.

Ecosystem services provided

Cork is a low-density product that provides good thermal, acoustic, and vibration insulation as well as being water-resistant. Female cork is traditionally used to make wine stoppers, while male cork can be crushed into granules and transformed into insulation panels. In order of importance, cork-growing forests are most commonly found in Portugal, Spain, southern France, and the south-west of Italy. Rare at a global level, these suberaie are recognized as a habitat of Community interest in Europe and fulfil an invaluable ecological role in terms of biodiversity, soil conservation, carbon fixation, and preservation of water resources.

Expert recommendation

Quercus suber requires intensive management since it is competitively inferior to other species. Its potential spread is limited by its climatic and edaphic requirements, though climate change may promote its dissemination. It is also an interesting tree species for crystalline soils. The cork oak is native to Europe and not invasive.

RHUS TYPHINA L.

Staghorn sumac

octovec

Essigbaum

Sumac vinaigrier

Sommacco americano

Main characteristics:

- Native to eastern North America.
- Deliberately introduced to many parts of the temperate region as an ornamental plant.
- Highly adaptable to different environments – a true habitat generalist.
- Has pronounced invasive potential due to its high reproduction rate and colonization capacity.

Management and use in urban areas in the Alpine space

The staghorn sumac is an ornamental plant that provides enjoyment throughout the year. It is valued for its coloured foliage in autumn as well as its interesting fruits, which persist on the tree during winter. Its vigorous suckering habit makes it unsuitable for smaller gardens, however. Where they are invasive and cause problems, trees must be cut and their roots excavated, and emerging new shoots must be removed regularly. In the case of locally occurring undesired propagation by seed, female trees should be targeted for restriction or removal first, as *Rhus typhina* is a dioecious species.

Tree site conditions and threats to be considered

Staghorn sumac trees can grow under a wide array of conditions, but they are most often found on dry and poor soil where other plants cannot survive. The species prefers sunny, warm sites and generally has low fertility requirements, which enables it to endure diverse soil types from coarse to fine. As a pioneer species, it also thrives in polluted city air and can even establish in pavement cracks. Dangerous pathogens for *Rhus typhina* include the fungus species *Fusarium oxysporum*, *Botryosphaeria ribis*, and *Cryphonecria parasitica*. *Fusarium oxysporum* causes wilting, yellowing, and decline and dieback of young and mature trees.

Invasiveness and risks

Recognized as an invasive species in various countries. Its invasiveness is achieved through relatively long-distance seed dispersal and especially through spreading via rhizomes (horizontal underground stems). This vegetative propagation allows the staghorn sumac to form clonal populations, particularly in disturbed areas. It invades various habitats such as forest edges, clearings, scrubland, waste ground, abandoned fields, and gardens. Although it is not considered poisonous, several studies have confirmed allergenic and allelopathic effects. The most effective way to deal with introduced invaders is to identify them as early as possible and attempt to eradicate or at least control them before they can spread widely. In addition to its invasive behaviour, the high content of antifeedants in *Rhus typhina* leaves can distinctly inhibit the survival and fecundity of many insects.

Ecosystem services provided

The staghorn sumac provides many ecological, protective, and aesthetic functions. For example, it is highly effective at retaining water and soil due to its colony-forming growth pattern. It can also be used in restoration efforts to improve degraded areas. Due to the high water content and low calorific value of its leaves and wood, it is also recommended for creating fire-resistant tree belts. For wildlife, *Rhus typhina* is not only a source of fruits but also important for deer browsing. Many kinds of pollinators can be found visiting its flowers, and it is a valued source of nectar for honey production.

Expert recommendation

Rhus typhina is a widespread plant valued not only for its ornamental qualities but also for its many other attributes such as edibility, healing properties, interesting wood, dye content, and adaptability to poor habitats. On the other hand, it is known to be a tree species with invasive potential, which somewhat limits its wider applicability and necessitates a certain amount of caution in cultivation. However, since most of its invasive potential is based on its vegetative rather than generative spread, its ability to invade larger areas in nature is relatively limited. Its roles in the environment are both positive and negative. From an arboricultural perspective, *Rhus typhin*a has several undesirable characteristics including its fragile and breakable branches. It is in fact a very dangerous tree for climbing, since adult trees often also have decayed roots or rhizomes and are thus prone to collapsing. Its vegetative propagation can be a problem in sites lacking regular surface maintenance.

ROBINIA PSEUDOACACIA L.

Black locust

navadna robinija

Gewöhnliche Robinie

Robinier

Robinia

Main characteristics:

- Popular ornamental tree in parks and urban forests.
- Light-demanding, fast-growing species armed with spines.
- Does not tolerate wet or compacted soils.
- Successful invader capable of colonizing a broad range of disturbed sites, including urban habitats.

Management and use in urban areas in the Alpine space

Due to its ability to tolerate high levels of air pollution, salinity, drought, and light intensity as well as low soil quality, the black locust is frequently planted as a solitary tree or in groups in urban parks, or as a linear feature along roads. It does not tolerate much pruning and cutting. Its ability to withstand air pollution in particular makes it popular as a park and avenue tree within cities in the Alpine space. It is also attractive for landscape gardeners and often used as an ornamental tree. Many horticultural varieties with interesting features like yellow foliage, monophyllous leaves, thornless branches, or weeping habitus have been bred. Low-statured cultivars are suitable for aesthetic crown formation by pruning.

Tree site conditions and threats to be considered

In general, *Robinia pseudoacacia* exhibits a high degree of ecological plasticity. It transplants well and is an appropriate plant for unfavourable urban sites, though it does not tolerate the wet or compacted soils that commonly occur in paved city environments. It can grow well on dry soils but requires sufficient light. Two major pests attack the black locust: the locust borer and the locust leaf miner, both of which can cause serious damage to trees. Possible diseases include canker, powdery mildew, leaf spots, wood rot, and verticillium wilt.

Invasiveness and risks

Besides thorns, the species also has poisonous seeds, leaves, and bark. In addition, it has brittle branches that can break in strong winds. Mechanical damage to roots or trunks causes vigorous clonal recruitment, with black locusts sending out long underground root suckers that not only become a maintenance problem but can also disrupt nearby gardening areas. The species is also extremely resistant to disturbance. Under unfavourable light conditions, it creates a persistent bud bank including buds on roots, stems, and branches, allowing rapid reaction to increased light availability after the disturbance ceases. Both climate change and planting for forestry and landscaping may increase the range of urban habitats colonized by *Robinia pseudoacacia* in the future.

Ecosystem services provided

The black locust is planted for multiple reasons. Its root system enriches the soil, benefiting certain locations in need of more nitrogen. The honey from its flowers is well-known and popular, and the flowers themselves can be used in the perfume industry. It also serves as a good erosion control plant due to its easy establishment and rapid early growth. Has limited value as a wildlife food but provides excellent cover when planted in disturbed areas, and can serve as a source of high-quality industrial wood and firewood.

Expert recommendation

Urban and industrial environments, including polluted or salty soil, are not excluded from the black locust's invasive spread. Colonized disturbed sites in the vicinity of urban areas can serve as donor populations for its spontaneous spread into urban forests and other green areas within cities. *Robinia pseudoacacia* is both beloved and despised, with its positive economic and negative environmental impacts generating controversial views and causing conflicts of interest between different groups with regard to its value (nature conservation, forestry, urban landscaping, beekeepers, general public, etc.). Several ornamental cultivars have been bred for round crowns, pink flowers, and an absence of spines, and these varieties are preferable for many green urban locations. Can be highly invasive owing to its prolific root suckers, particularly in warmer climates.

STYPHNOLOBIUM JAPONICUM (L.) Schott

Pagoda tree

japonska sofora

Pagodenbaum

Sophora du Japon

sofora del Giappone

Main characteristics:

- Formerly included in a broader interpretation of the genus *Sophora*.
- *Sophora japonica* (L) is a synonym.
- Despite its name, it is actually native to China and Korea.

Management and use in urban areas in the Alpine space

The pagoda tree is resistant to emissions and road salt and is therefore a favoured tree in parks and along roads. On public grounds, regular tree inspection is obligatory and appropriate maintenance must be performed. The crowns can and should be cut regularly, removing deadwood from them – preferably in autumn rather than in spring. In the Alpine space, the species is widely used for ornamental purposes in parks and gardens and along streets.

Tree site conditions and threats to be considered

Styphnolobium japonicum prefers sunny locations that are somewhat sheltered from wind. In its native range, it grows in deciduous forests as well as in valleys and along riverbanks, avoiding compacted soils and stagnant water. The species is very robust in terms of low temperatures, heat, drought, and salt influence. Studies in German cities have also shown that it is generally winter-hardy but only partially frost resistant. It is recommended to plant pagoda trees only in protected locations, as their branch strength is rated as medium.

Invasiveness and risks

The pagoda tree has been reported as invasive in the United States, Australia, South Africa, and in some parts of the Iberian Peninsula. Its roots and stems can be infested by *Armillaria mellea*, causing severe damage. There are otherwise only few pests and diseases that affect the species, however; they include the fungus *Botrytis cinerea* and the insect *Bruchophagus sophorae*, both of which can cause seed damage.

Ecosystem services provided

Due to their late and magnificent blossom, pagoda trees are good for pollinators and represent preferred bee targets. The species offers moderate microclimate regulation and soil quality improvement capabilities. Its shading capacity is rated as moderately dense in leaf as well as out of leaf. There can be litter issues with dry fruit and twigs.

Expert recommendation

Styphnolobium japonica is very tolerant of dry conditions and resistant to urban stressors. As its crown becomes very broad, it provides good shade but is only suitable for areas with ample space such as parks. The species has recently been planted more and more frequently, especially as a street tree. It can also be found in some parks and hotel gardens.

THUJA OCCIDENTALIS L.

Northern white cedar

ameriški klek

Abendländischer Lebensbaum,
Gewöhnliche Thuja

Thuya occidental

Tuia occidentale

Main characteristics:

- Evergreen tree species related to the family *Cupressaceae* with a native range in southern Canada and the northern United States.
- Popular hedge plant.
- Its essential oil is used in medicine and cosmetics.

Management and use in urban areas in the Alpine space

The northern white cedar occurs in all countries associated with the Alpine space and is mainly used for ornamental purposes in parks, private gardens, and cemeteries. Numerous varieties exist, some of which are narrow, columnar, or conical, like "Brandon", "Degroot's Spire", "Emerald", "Nigra", and "Pyramidalis". Pruning is necessary in case of fungal or insect infestation, and in cases of intensive infestation, the entire plant must be removed. On public grounds, regular tree inspection is required. As an erect tree species, *Thuja occidentalis* requires ample growing space. Its branch strength is rated as strong and its root damage potential as moderate.

Tree site conditions and threats to be considered

Thuja occidentalis is quite sensitive to drought stress. In combination with this factor, other pests and diseases that damage individuals can also occur. The species needs ample moisture, and soils such as silty loam with good water storage capacity are most suitable for it. Because of its shallow root system, it is rather vulnerable to windthrow. Individuals infected with *Armillaria mellea* should be removed with their entire root system, as the fungus establishes a large network of rhizomorphs in the soil. The beetle *Lamprodila festiva* has been observed on northern white cedars in Romania; this insect has already been recognized as a new invasive pest in some European countries and could increasingly infest the Alpine region in the future.

Invasiveness and risks

According to EASIN (European Alien Species Information Network), the species has an unknown/low invasive potential. There are no references reporting invasiveness of *Thuja occidentalis* so far.

Ecosystem services provided

The northern white cedar's shading capacity is rated as dense in leaf. It offers a high level of air pollution mitigation as well as moderate soil quality improvement and CO_2 sequestration capabilities. Its dried fruits may cause litter issues.

Expert recommendation

Thuja occidentalis is a true mass product as one of the most popular hedge plants. It has problems with drought, and there has been an increased occurrence of pests (*Thuja* bark beetle) in recent years due to the species' intensive use over the past decades. The demand for northern white cedars remains high, and by now every second privacy hedge in South Tyrol is planted with the species.

TSUGA CANADENSIS (L.) Carrière

Canadian hemlock

kanadska čuga

Kanadische Hemlocktanne

Tsuga du Canada

Tsuga canadese

Main characteristics:

- Native range extending from Quebec to Alabama.
- Commonly used as an ornamental tree in Europe.
- Tannins and turpentine can be obtained from its bark.
- Endangered by the tiny sap-sucking Hemlock woolly adelgid (*Adelges tsugae*) in its native range.

Management and use in urban areas in the Alpine space

The Canadian hemlock is a common ornamental tree in Europe that combines well with many deciduous and coniferous trees. It tolerates pruning and shaping well and can also be trained as a dense formal hedge. The species needs ample moisture, and it should not be planted along roadsides where salt is used in winter, as its foliage is sensitive to salt spray. It is also poorly adapted to use as a windbreak tree, since wind exposure causes dieback in winter. Further drawbacks include a fairly low resistance to urban stress, intolerance to very wet or very dry soils, and susceptibility to attack by the hemlock woolly adelgid. The tendency of *Tsuga canadensis* to shed its needles rapidly after being cut down makes it unsuitable as a Christmas tree. Its branch strength is rated as strong and its root damage potential as moderate.

Tree site conditions and threats to be considered

The ecological characteristics of the Canadian hemlock include a high degree of shade tolerance related to its crown architecture, light saturation properties, and root/shoot development rates at low light levels. It is one of the most drought-sensitive tree species native to eastern North America, where large numbers of individuals are often killed by serious drought events, possibly because of the shallow root system.

Invasiveness and risks

Not invasive.

Ecosystem services provided

The Canadian hemlock is considered a "foundation species" owing to its strong influence on the structure and function of the riparian ecosystems in its native range. Its shading capacity is rated as dense.

Expert recommendation

Tsuga canadensis can be found in association with many forest mushrooms such as the edible *Ramaria flavosaponaria*. It is sometimes used for hedges but is considered inferior in this regard to *Tsuga heterophylla*, the western hemlock.

ULMUS PUMILA L.

Siberian elm

sibirski brest

Sibirische Ulme

orme nain de Sibérie

olmo Sibiriano

Main characteristics:

- Native to Asia; the last tree species encountered in the semi-desert regions of central Asia.
- Grows fast and rapidly resprouts from roots; also exhibits good drought tolerance.
- Unlike most elms, the Siberian elm can self-pollinate.

Management and use in urban areas in the Alpine space

In the 20th century, Siberian elms were widely planted in Europe because of their resistance to Dutch elm disease. The species is also resistant to frost, but prone to branch and twig breakage from wind, snow, and especially ice. Its shading capacity is rated as moderate in leaf as well as out of leaf, while its branch strength is rated as weak and its root damage potential as high. The dry fruits can cause litter issues. Due to its ability to grow in areas with pollution and salinity, the Siberian elm could be a suitable species for planting in cities.

Tree site conditions and threats to be considered

Ulmus pumila has a rounded or spreading crown shape and requires ample growing space. It prefers fertile, well-drained soils with abundant sun, yet is also extremely adaptable to harsh conditions such as drought, cold winters, long floods, and poor, dry soils. Only highly acidic soils are problematic. The species exhibits considerable variability in terms of its resistance to Dutch elm disease; for example, trees from north-western and north-eastern China are able to withstand it significantly better than those from central and southern China.

Invasiveness and risks

Its ability to quickly resprout from roots makes the Siberian elm very competitive; it is even considered invasive in some countries like the United States. In Europe, it has spread widely in Spain and Italy and hybridizes with the native field elm (*Ulmus minor*), which may constitute a conservation concern. The hybridization potential between the two species is high, and repeated hybridization could result in genetic swamping of the field elm. The result could be the evolvement of invasiveness in the introduced species.

Ecosystem services provided

The Siberian elm is mostly used for windbreaks and to control soil erosion. Its resistance to Dutch elm disease has been successfully bred into various elm hybrids.

Expert recommendation

Ulmus pumila is usually a medium-sized, often bushy deciduous tree growing up to 31 m in height, with a diameter at breast height of up to 1 m. it is highly susceptible to damage from many insects and parasites, including the elm leaf beetle *Xanthogaleruca luteola*, the Asian elm zigzag sawfly *Aproceros leucopoda*, elm yellows, powdery mildew, cankers, aphids, leaf spot and, in the Netherlands, the coral spot fungus *Nectria cinnabarina*. It is the most resistant of all elms species to verticillium wilt, however.

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