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Management of non-native tree species in forests of the Alpine space

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ALPTREES

MANAGEMENT OF NON-NATIVE TREE SPECIES IN FORESTS OF THE ALPINE SPACE

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The INTERREG Alpine Space programme is a European transnational cooperation programme for the Alpine region. It provides a framework for facilitating cooperation between key economic, social, and environmental players in seven Alpine countries, as well as between various institutional levels.

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FOREWORD

Aleksander MARINŠEK, Katharina LAPIN

The black locust (*Robinia pseudoacacia*) is a fast-growing tree native to eastern North America. Alongside the northern white cedar (*Thuja occidentalis*), it was one of the first alien tree species introduced to Europe more than 400 years ago. For this reason, we classify the black locust as a non-native tree species (NNT) in Europe. More precisely, we classify it as an invasive NNT because of its characteristics. The northern white cedar, on the other hand, has not developed invasive characteristics and is therefore simply classified as NNT. The presence of various such (invasive) NNT in the European area is a reality since their introduction, and the Alpine region is no exception. On average, NNT are estimated to cover around 4% of European forests.

Most NNT were introduced to the Alpine region intentionally. They were promoted in forested and urban areas for their various positive characteristics: some NNT have higher yield, higher timber value, high aesthetic value, stronger root systems, etc. Only few NNT came to the Alpine region unintentionally or spontaneously. Many species entered the region at some point, but most did not naturalize and thus did not become established. In the course of the ALPTREES project, we have been able to identify more than 530 NNT in the forests and urban areas of the Alpine space. The majority of these NNT can only be found in urban areas and provide ecosystem services not related to forests.

Climatic conditions have changed since the first attempts to introduce and promote NNT in our forests and cities. What is more, climate change is occurring faster in the Alpine space than in other areas, making the region more vulnerable. Climate change has also altered the characteristics of certain established NNT, with some of them becoming more competitive and invasive under the new conditions – in particular when native tree species can no longer thrive optimally in their forest habitats due to the changing climate. Research indicates that certain NNT may be better adapted

to changing climatic conditions, and we therefore need to consider their presence on specific sites. Future climate conditions and increasing CO_2 concentrations are expected to affect site suitability, productivity, species composition, and biodiversity directly as well as indirectly. Whether we see NNT as a threat or a potential, they need to be systematically managed – especially those that are already naturalized and present in our area. Although NNT certainly evoke a range of different associations and emotions in people, careful integration of tested and suitable NNT into future forest management strategies may offer great potential for climate change adaptation and mitigation. In critical and vulnerable ecosystems such as the Alpine space, however, potential risks and benefits need to be weighed particularly thoroughly before management decisions are made. In addition, the definition of NNT includes hundreds of different species with diverse traits, shapes, ecological niches, levels of invasiveness etc. – often even within individual taxa. For this reason, we must be cautious when speaking about the entire category of NNT in general terms and should consider their employment on a case-by-case, site-by-site, and goal-by-goal basis.

Whether native or non-native, management measures can increase the ecological, economic, and social value of tree species. The foundation for managing NNT should be a profound awareness of their ecological and physiological characteristics. Most importantly, their management should be based on two fundamental aspects: the experience we already have with NNT, and detailed knowledge of the benefits and risks associated with them.

The expected benefits and potential risks of NNT for European geographic regions have polarized the opinions of experts and citizens. The activities within the ALPTREES project – which is part of the Alpine Space programme, a European transnational cooperation programme for the Alpine region – are designed to bring us closer to achieving the essential goal of providing a transnational strategy for a decision-making support system on responsible use and management of non-native tree species in the Alpine region.

<table>
<tr><td rowspan="3">Native tree species are tree
species of natural, post-glacial forest development in the Alpine region.</td><td colspan="3">Non-native tree species (NNT), also known as “non-indigenous”, “alien”, “introduced”, “allochthonous”, or “exotic” tree species, breeds, or hybrids in the Alpine region whose presence there is the result of intentional or unintentional introduction by humans.</td></tr>
<tr><td rowspan="2">Archaeophytes include NNT intentionally or unintentionally introduced to the Alpine region (mostly from Asia and north Africa) that became naturalized there prior to the year 1492.</td><td colspan="2">Neophytes include NNT intentionally or unintentionally introduced to the Alpine region that became naturalized there after the year 1492 (when Christopher Columbus arrived in the Americas and the global trade in non-native species began).</td></tr>
<tr><td>Non-invasive tree species are NNT that have not yet exhibited any indication of negative effects, or whose effects are unknown.</td><td>(Potentially) invasive tree species are NNT whose introduction, establishment, and/or spread pose potential or actual risks to native biodiversity, ecosystem functions, or socio-economic aspects including human health.</td></tr>
</table>

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

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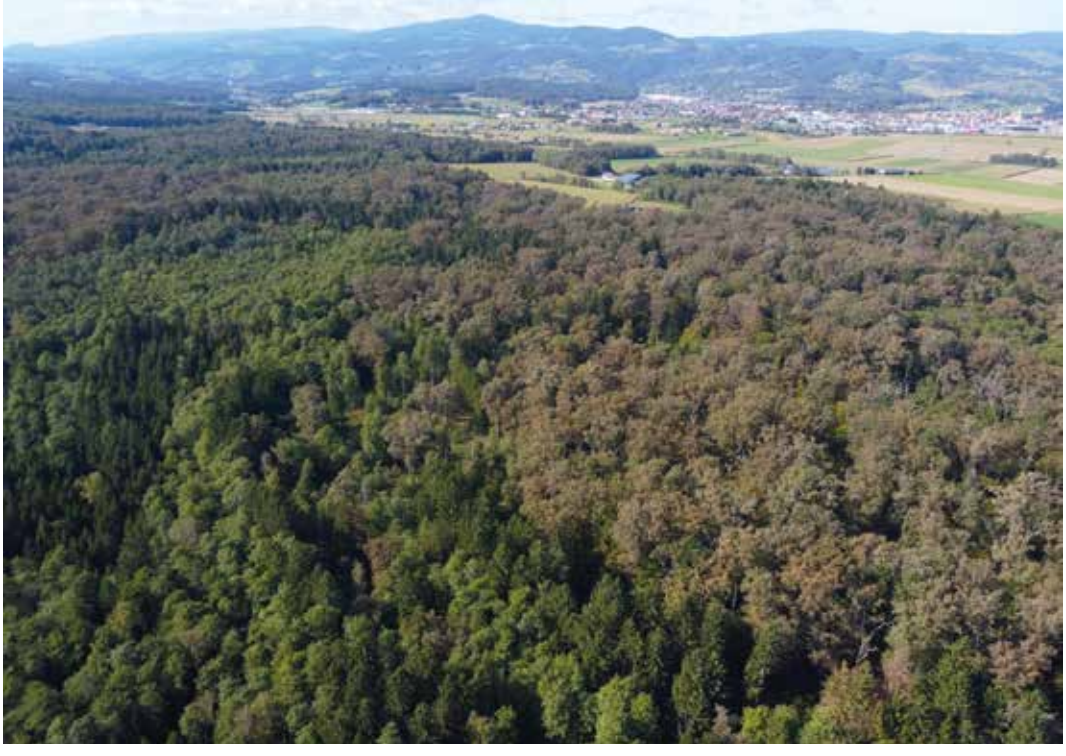

RISKS AND BENEFITS OF NON-NATIVE TREES IN THE ALPINE SPACE

Katharina LAPIN

Climate change and human activity represent major threats to the ecosystems in the Alpine space. Therefore, adaptation efforts are required to respond to expected negative effects on Alpine environments, economies, and societies. Non-native trees (NNT) can support the adaptation of European forests and urban areas to climate change, but they simultaneously entail risks for biodiversity and ecosystem functions. Many efforts have already been undertaken to address these risks, but there are so far no recommendations or strategies for the management of NNT in the Alpine region at the European level, and only very few at the national/regional level, that consider the challenges of climate change.

NNT have been used in Central Europe for more than 200 years. The primary motives for their introduction were the increase of wood production and resistance to harmful organisms. In addition, cultivation of NNT has been discussed as an effective adaptation measure in forestry against the background of the already noticeable impacts of climate change during the last two decades. For example, some of the NNT tested so far have a higher resistance to extreme climatic conditions, such as drought, than native species. Other potential benefits of NNT include contributions to the local bioeconomy and to urban and peri-urban green infrastructure as well as the mitigation of natural hazards. On the other hand, the cultivation of NNT can entail certain ecological risks such as biodiversity loss in forest ecosystems, displacement of native species, or site alterations. From a nature conservation perspective, the use of other native tree species – or other provenances of existing species – is therefore clearly preferred whenever possible in the case of forest conversions necessitated by climate change. Forestry, on the other hand, sees the

increased cultivation of NNT as an opportunity to establish climate change–resistant mixed stands with high growth performance while simultaneously reducing the risk of stand failures due to shifting climate patterns. In addition, the loss of important native broadleaf tree species that were considered stable options during the previous century (ash, elm, chestnut, beech) already needs to be compensated for. Sustainable timber production on managed lands also plays an essential role. Nevertheless, both nature conservation and forestry have the common goal of continuing to ensure the important ecosystem services of forests, such as preventing erosion and protecting water, biodiversity, and the climate as well as providing the greatest possible carbon storage capacity. Finally, the cultivation of NNT can also have an impact on the landscape appearance of forests.

CLIMATE CHANGE IMPACTS ON FORESTS

Martin BRAUN and Katharina LAPIN

Projections show that climate change will have a considerable impact on trees in forests by altering the frequency, intensity, duration, and timing of factors including precipitation, drought, non-native species, insect and pathogen outbreaks, wind and ice damage, and gravitational mass movement (Dale et al., 2001). Trees are believed to have limited adaptive capacity to respond to extreme temperatures and rapid climatic and environmental change (Lindner et al., 2010). Furthermore, climate change is expected to be one of the main future causes of biodiversity loss worldwide (Sala, 2000), and research shows that the extinction of species from numerous taxa will follow (Thomas et al., 2004). It is by now widely accepted that climate change is a global phenomenon, that CO_2 emissions are the main cause of climate change, and that deforestation is currently responsible for almost 20% of the annual global emissions of CO_2 (Diamandis, 2014).

The impacts of climate change are expected to be particularly severe in the Alpine region. A shifting precipitation regime will likely lead to more intense and frequent drought events during summers (Fenning, 2014). Droughts tend to lead to reductions in growth and CO_2 uptake in subsequent years (e.g., summer drought study conducted by Ciais et al., 2005), and successive drought events likely affect tree quality and increase mortality, leading to changes in species composition and forest structure. Another challenge in the Alpine region is the likely increase in mean temperature, which will cause increased evaporation and thus further changes to precipitation patterns, potentially resulting in even more severe drought episodes impacting forest growth and resilience (Fenning, 2014). Although forest fires are currently not a pressing problem in the Alpine space, fire intensity and frequency are also likely to increase (Dale et al., 2001). On a large scale, forest tree species and communities will

experience increased stress, and cultivation will no longer be possible in lowland areas, thereby strongly affecting some habitats and possibly leading to impacts on biological diversity. The ideal climate zones for many tree species in Europe will shift northwards and upwards. For the Alpine regions, this implies that climate change will further alter the distribution of many species, with an upward shift in elevation for various plant communities (Hastings and Turner, 1965) and earlier onset of spring (according to phenological observations) for most tree species. So-called ecologically effective population densities serve as guidelines for determining the minimum densities of individuals necessary to maintain critical interactions and ensure resilience against ecosystem degradation and extreme events (Soule et al., 2003).

Adaptation requirements for forests

Non-native trees (NNT) are sometimes viewed as part of a solution for adapting forests to future climate conditions. Bioclimatic envelope modelling (e.g., Araújo and Peterson, 2012; Pearson and Dawson, 2003) can help to provide a first assessment of NNT viability under expected conditions. Subsequently, factors such as biotic interactions, soil conditions, extreme sites, evolutionary change, dispersal ability, and adaptation potential of native tree species to future climatic conditions must also be appropriately considered (Araújo and Peterson, 2012; Pearson and Dawson, 2003; Sutmöller et al., 2008), along with the fact that large areas of forests in the Alpine space are secondary forests and do not reflect the potential natural distribution (Brune, 2016).

Since no significant effort has been made during the past two decades to mitigate habitat loss and protect biodiversity, it is likely that more areas will need to be set aside for conservation to increase the resilience of forests to stochastic climatic events. Safeguarding and increasing biodiversity is seen as an important step in boosting the resilience of Alpine space forests to future climatic conditions. The introduction and use of NNT will play an ambiguous role in this context, since their introduction in conservation areas can have undesirable and unintended effects on the resilience of

habitats. Potential positive use cases, on the other hand, can support the stabilization of ecologically compromised areas and ensure a consistent raw material supply under future climatic conditions.

The forest-based sector will likely have to adapt economically due to changes in requirements for suitable trees, which will lead to a decline in softwood available for further processing. This in turn will create a need for research and development regarding hardwood processing technologies, as well as adaptation to a wider variety of tree species in general to optimally use and allocate the available biomass supply. In this context, adaptation requirements in the Alpine space include the cultivation of suitable tree species from similar habitats in climatically appropriate regions (i.e., assisted migration), respectively the introduction of NNT.

Regarding the selection of trees for future use, the effects of environmental factors on tree resistance to insects (in direction and intensity) seem to depend on available resources, the intensity of stress supported by the individual tree species (i.e., its resilience), and the nature of specific insect guilds (i.e., groups of species that exploit the same resource in related ways) (Lieutier, 2006). Important steps to consider in terms of forest management are therefore:

- Investigation of potential climate-induced habitat dynamics and efforts to designate more areas for conservation as well as some for intensification.
- Careful examination of current and future climatic suitability of currently employed propagation material.
- Investigation of ecosystem risks, benefits, and trade-offs of introducing established species from different provenances vs. NNT.
- Analysis of potential habitat effects caused by the introduction of NNT.
- Ensuring that prerequisites and intended targets are met in forests available for wood supply as well as conservation areas.

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MANAGEMENT PRINCIPLES FOR SUSTAINABLE USE OF NON-NATIVE TREES

Aleksander MARINŠEK

Forests in the Alpine region are an important part of the landscape and provide various ecosystem services and functions that are crucial for nature-based solutions for a sustainable society. Among the most important of these are:

1. productive functions (timber and non-timber products),
2. protective functions in places where human populations and ecosystems are permanently threatened (soil erosion, landslides, snow avalanches, biodiversity conservation), and
3. social functions such as recreation, aesthetic functions, and many others.

Of particular importance in the Alpine region are the protective functions of forests, which have a stabilizing effect on the natural environment (water purification and circulation, precipitation, air circulation, temperature, macro- and microclimate). In addition, the interdependence of all three forest function groups in the Alpine region is profound, and well-planned forest management is therefore required. Sustainable forest management concepts need to consider the compatibility between forest functions, ecosystem properties (Führer, 2000), and different stakeholders. Add to this interconnectedness of functions the diverse requirements of different stakeholders, the increasing effects of climate change, and the presence of existing and future non-native tree species (NNT), and successful forest management can become a very challenging task. Owing to the high complexity and heterogeneity of overall forest management, we will focus only on the principles for managing NNT. Forest management principles may vary between countries in the Alpine region, but management principles for sustain-

able use of NNT should generally be the same. And regardless of whether the species are native or non-native, management interventions can increase their economic, ecological, and social value.

The most important guidelines for forest management should be those formulated by the Convention on Biological Diversity (Second Ministerial Conference on the Protection of Forests in Europe, MCPFE (16–17 June 1993, Helsinki/Finland)): "Native species and local provenances should be preferred where appropriate. The use of species, provenances, varieties or ecotypes outside their natural range should be discouraged where their introduction would endanger important/valuable indigenous ecosystems, flora and fauna." NNT may still be used even when they are considered invasive, if their negative impacts will likely not occur in the area of usage, and if their populations can be controlled with little effort. If possible, native species should always be preferred, while NNT can be considered if they are clearly superior to native species for achieving forest management objectives (Stupak et al., 2011), or if native species are no longer able to fulfil crucial forest functions or ecosystem services. But there is a risk if no negative impacts are identified in the short term in the area where they are used, they will most likely occur in the future. Therefore, the use of NNT can also be highly controversial, as they can cause significant environmental changes as part of large-scale plantations or when they spread beyond their intended area of introduction into natural ecosystems (Pötzelsberger et al., 2020b).

Some NNT species have existed in our forests for centuries, and others will arrive in the near future. The reality in the EU is that around 4% or 8.5 million ha of European forests are currently composed of NNT species, with large regional differences (Pötzelsberger, 2018; Brus et al., 2019). Most of these NNT were intentionally introduced into forests after being initially used in parks for aesthetic purposes, mainly from the 19th century onwards (Nyssen et al., 2016). The criteria for selecting tree species were experience, ease of cultivation, productivity (economic attractiveness), and in some cases the potential to improve site conditions (Pötzelsberger et al., 2020a).

In general, our NNT management in the Alpine region should be based on EU, national, and sub-national legislation, and furthermore on whether a specific NNT species:

- is long-established in the respective area/forest site (with the corresponding experience we have with it),
- is a newcomer (spontaneously or unintentionally introduced NNT),
- is a species we want to promote,
- is (potentially) invasive or not,
- is harmful to human health by way of allergenic pollen or other plant tissue (especially in urban contexts),
- brings benefits, risks, or both to the environment, economy, and human health and wellbeing.

For NNT management, we must therefore first know which NNT are present within a given area. Overall, Brus et al. (2019) determined at least 145 NNT occurring in European forests (excluding trials and arboreta), with almost half of them originating in North America. With such a large number of NNT, management principles should generally be based on our experience and knowledge along with the risks and benefits accompanying the presence of NNT under existing legislation. The following three legal instruments are relevant to the introduction, use, and management of NNT at the EU level: (1) Council Directive 1999/105/ EC of 22 December 1999 on the marketing of forest reproductive material, (2) Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (the "Habitats Directive") and (3) Regulation (EU) No 1143/2014 on the prevention and management of the introduction and spread of invasive alien species (IAS), which includes invasive NNT. Regarding the national and subnational levels, Pötzelsberger et al. (2020b) reported 335 relevant legal instruments regulating the use of NNT in place in the investigated 116 geopolitical legal units across the EU in June/July 2019.

Only some NNT species are well known and studied enough for us to be aware that they can represent both benefits and risks in a changing environment. Because rising CO_2 concentrations and further climate warming are expected to affect

site suitability, productivity, species composition and biodiversity. The mismatch between climate change and tree adaptation will have serious implications for forest growth and composition – and thus important consequences for management and conservation (McKenney et al., 2009). NNT can be part of the solution for adapting to such changes in forest ecosystems, but at the same time they pose risks to biodiversity and ecosystem functions. We therefore need a suitable risk assessment tool especially for NNT (Bindewald et al., 2020) that should be site-specific and topical.

Over the last centuries, many NNT have only been tested and planted on a small scale. Documentation of these trials and plantations is patchy and not centrally available (Pötzelsberger et al., 2020a). Our forest ecosystems are changing drastically due to increasing global warming, and some forest sites and forest types are more heavily invaded by NNT than others. For the Alpine region, some NNT – especially those with an invasive character and the ability to adapt to changing forest site conditions – are expected to spread spontaneously through our semi-natural forests, including *Robinia pseudoacacia*, *Ailanthus altissima*, *Acer negundo*, *Quercus rubra*, and others. Such expansion at the expense of indigenous growth space is already a major problem from the point of view of biodiversity and ecosystem functioning, and it is expected to become even more serious. For a long time, we have been confronted with the phenomenon of invasions by various NNT, and we still need to study three different aspects: invasiveness of species, invasibility of ecosystems, and impacts of invasive species. Invasive NNT affect the environment at different levels including competition, hybridization, disease/pest transmission, and chemical, physical, or structural impacts (Blackburn et al., 2014). Regarding such invasions, our efforts should focus on the restriction and eradication measures included in the respective management plan. Such measures include mechanical, chemical, and biological methods for eradicating and restricting the spread of NNT. To prevent the further spread of light-demanding species such as black locust and tree of heaven in particular, Meloni et al. (2016) suggest refraining from completely opening the canopy in forest stands as a particularly prom-

ising silvicultural measure. We must also strive to prevent the spread of NNT from existing plantations into sensitive habitats and monitored buffer zones are an appropriate measure in this regard (Vor et al., 2015) – especially in well-managed forest landscapes and for NNT that can be easily removed (species that do not resprout and do not form root suckers).

Whenever we decide to promote certain (tested) NNT in our forests, proper selection of provenance material is essential, as some important NNT originate from large distribution ranges in which numerous races, ecotypes, and climes have evolved (Pötzelsberger et al., 2020a). When using NNT seeds and planting material from our own seed stands, it is important to be aware that the loss of genetic diversity and even inbreeding depression can be a disadvantage (Wojacki et al., 2019): unlike many native species, introduced trees often do not have large populations in their area of introduction. Another important issue is the response of NNT to future climatic conditions, and this is the area in which provenance testing can be useful. For example, a provenance that works relatively well in one location may not be suitable for another potential area of use with similar conditions in the future due to climate change (Chakraborty et al., 2015, 2019). Some authors (Correia et al., 2018) believe that adaptation to extreme events may even be more important than adaptation to changing average values of environmental variables. A promising example in the Alpine region could be the Douglas fir (*Pseudotsuga menziesii*) as a replacement for the Norway spruce, which is disappearing from spruce, beech, and silver fir forests due to climate change and past management mistakes. The Douglas-fir can be also combined with native tree species in mixed forests. Invasiveness is not an issue in such mixed Douglas fir stands; in fact, the early growth of the Douglas fir needs to be supported due to its relatively high light requirements. However, in our rapidly changing ecosystems, further studies and monitoring are required.

In general, the integration of NNT into mixed forest stands with native tree species is easiest and safest when the ecological characteristics of the introduced NNT are similar to the native species and the NNT do not exhibit strong dominance behaviour (Spiecker et al., 2019).

Pötzelsberger et al. (2020a) note that the reputation of NNT and the question of their further spread in Europe are fraught with hope, prejudice, scepticism, and rejection. A transnational strategy for the management and responsible use of NNT – like the efficient and unified policy regarding NNT in the Alpine space– could lead us to a sustainable, unharmful coexistence with numerous NNT. And this is one of the main ALPTREES project objectives.

General recommendations for the sustainable use of NNT in forests are as follows:

1. Promote native tree species wherever possible.
2. Introduce assisted native species migration (Williams and Dumroese, 2013), transferring and testing species from adjacent regions in south-eastern Europe to northern parts of Europe.
3. If needed, genetic breeding of native tree species should take priority over the use of NNT.
4. If we choose to promote NNT, the respective tree species should only be used if knowledge and/or experience have shown that their invasive impacts can be controlled, and effective mitigation measures are in place (Forest Stewardship Council principles and criteria for forest stewardship. FSC-STD-01-001 V5-2 EN. Bonn: Forest Stewardship Council; 2015).
5. Consider relevant legislation.
6. Promotion of NNT species should only be allowed if the respective NNT are clearly superior to native species for achieving forest management objectives and those objectives do not compromise other possible ecological services.
7. Use of Site-Specific Risk Assessments (SSRA) which can be defined as assessments of the likelihood of the establishment, spread, and associated (potentially) undesirable consequences of NNT on individual forest sites.
8. Promote NNT only on sites with native tree species, except for species planted on agricultural soil like poplars.
9. Research and monitoring of NNT properties should focus on a wider range of species rather than only on established NNT species.

10. Use your own experiences with NNT and exchange knowledge.
11. Prohibit the planting of NNT with high ecological risks.
12. Preferably avoid monocultures of NNT; NNT should only be mixed into existing forests in defined proportions (depending on the individual NNT).
13. Choose the most suitable provenance or ecotype of NNT.
14. Be aware that besides climate change and extreme events, European pests and pathogens as well as the unvoluntary introduction of foreign pests and pathogens are potential threats to NNT (and to native trees).
15. Where invasive NNT are prevalent, containment and eventual eradication should be undertaken as part of silvicultural measures.
16. Educate people on the potential risks and benefits of NNT, including the importance of preventing their introduction and spread on one hand and their significance for climate change adaptation on the other.

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SITE-SPECIFIC RISK ASSESSMENT OF NON-NATIVE TREE SPECIES USED IN FORESTS ACROSS THE ALPINE SPACE

Anja BINDEWALD, Giuseppe BRUNDU, Silvio SCHUELER, Uwe STARFINGER, Katharina LAPIN

Introduction

Non-native tree species (NNT) are used in Alpine space forests because of their specific wood properties and fast growth rates, or to improve forestry and diversify the portfolio of suitable native tree species (Braun et al., 2021; Pötzelsberger et al., 2020). Especially when native trees are no longer able to fulfil crucial forest functions due to increasing global temperatures, NNT better suited to future climate conditions can be planted to adapt forest ecosystems and mitigate the negative effects of climate change (Bolte et al. 2009). However, large-scale cultivation of certain NNT can entail risks to biodiversity and related ecosystem services, and these species therefore require a dedicated risk assessment regarding their invasive potentials (Brundu et al. 2020). Particularly when NNT could spread into areas of high conservation value, their use near protected areas may conflict with nature conservation objectives (Campagnaro et al., 2018; D'Antonio & Flory, 2017). Such controversial NNT often cause debates about how existing and future forest stands should be managed and whether new stands should be promoted (van Wilgen & Richardson, 2014). It is thus important to assess the risks associated with the use of NNT to identify low-risk species that can be integrated into forest management.

In general, a risk assessment can be defined as the standardized evaluation of (potential) negative impacts associated

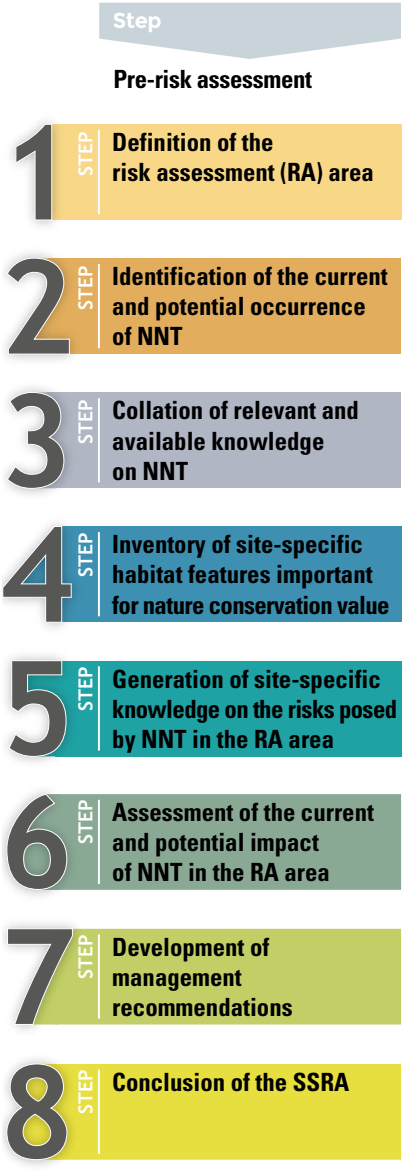

Figure 1: *Overview of the eight steps of the manual for Site-Specific Risk Assessments (SSRA) (Bindewald et al. 2021a); RA=risk assessment, NNT=non-native tree species.*

with the introduction, establishment, and spread of NNT (FAO 2019). In the INTERREG Alpine Space project ALPTREES, we developed a new methodological framework for "Site-Specific Risk Assessment" (SSRA) over the course of several workshops with our project partners and observers. Although a plethora of methods already exists, the novelty of the SSRA in comparison to other available methods is its foundation on a stratified assessment of risks posed by NNT that distinguishes between different ecosystem types, locations or sites. The SSRA therefore enables the regional context as well as the effectiveness of available management strategies for mitigating negative effects in the area of interest to be considered. It serves as a decision support system for the selection of sites, NNT, and silvicultural methods for taking advantage of the ecosystem services provided by beneficial NNT while limiting associated risks.

The SSRA manual

The SSRA manual offers a step-by-step guideline providing research institutes, forest enterprises, conservation managers, and local and national authorities with an end user–friendly framework for managing NNT sustainably. The overall aim of the SSRA is to support the decision where, how, and which NNT can be used to limit potentially associated risks in a specific area of interest. The SSRA is structured into eight steps, and for each step, certain target information needs to be gathered and analysed by the assessor(s) (Figure 1, Table 1) (see Bindewald et al. 2021a for comprehensive overview of the steps). Before assessing the risks of NNT in the eight steps, however, it is necessary to identify the needs, motivations, goals, and expected benefits of the SSRA. In this Pre-risk assessment, it should be clarified whether the objective is to assess the risks of a specific pre-selected NNT or multiple NNT. Figure 1 provides an overview of the individual steps and the respective aim. Table 1 shows the tasks to be performed in each step.

Table 1: *Steps and tasks of the manual for Site-Specific Risk Assessments (SSRA) (adapted from Bindewald et al. 2021a); RA=risk assessment, NNT=non-native tree species.*

STEP	TASK
	Identify the needs, motivations, goals, and expected benefits of the SSRA. Clarify whether the target is to assess the risks of one specific pre-selected NNT or multiple NNT.
STEP 1	Define the risk assessment area (RA area) by providing a geo-referenced and spatially explicit map. The SSRA can be performed at different spatial scales, i.e., at the local, landscape, or regional level.
STEP 2	Assess the likelihood of presence of the pre-selected NNT in the RA area. Support this step with monitoring data, observations, or personal communication from local experts or stakeholders.
STEP 3	This step is conceived as a desk survey. Compile relevant existing knowledge on the NNT and, if present in the RA area, its extent and distribution pattern. Consider the following information: ecology (e.g., spread and reproduction capacities), extent and distribution in the RA area, reported actual or potential positive and negative impacts on biodiversity or other ecosystem services (e.g., protective functions of forests) and human health, as well as available management options to mitigate risks.
STEP 4	Define the endangered area(s) within the RA area by compiling the relevant site-specific habitat features that account for the nature conservation value of the RA area. Consider all sites that are actually or potentially affected by the selected NNT based on existing knowledge.
STEP 5	Collect new evidence on the risks of NNT if knowledge gaps have been identified for the RA area based on the previous step. Increase site-specific knowledge, for example by 1) analysing systematically collected inventory data, 2) collecting new data in the field, or 3) applying ecological models to simulate the potential distribution of selected NNT.
STEP 6	Assess the likelihood and magnitude of negative impacts on the protected assets in the RA area. First, review and classify all collected information on potential impacts by level of evidence and relevance to the RA area. Use this evidence base to assess the magnitude of (potential) negative impacts for the different sites. Consider the reversibility of any negative impact and the options for controlling populations trough available management measures when making the final decision on the use of NNT.
STEP 7	Recommend appropriate measures for priority actions, local eradications, prevention of spread, or further monitoring for the entire RA area or for the endangered area within it. Indicate NNT with expected low risks. Consider feasibility, cost-efficiency, and stakeholder and public acceptance of the site-specific management measures.
STEP 8	Summarize key findings of Steps 1 to 7 by differentiating the potential negative impacts by location. For further communication, include the objective and the outcomes of the SSRA, a justification and limitation of the results, and the level of uncertainty in the assessment.

The outcome of the SSRA is to classify NNT into one of four categories with different management scenarios in the risk assessment area following the decision tree in Figure 2:

(a) NNT for which information is too scarce to arrive at a conclusive assessment of associated risks,

(b) NNT that currently pose no risks,

(c) NNT that can pose risks in some environmental contexts, and management practices exist that minimize such risks,

(d) NNT expected to always pose high risks that cannot be controlled through specific management measures.

Silvicultural adaptation strategies should focus on tree species in categories b) and c) (Figure 2), while improving the information base for risk assessments, for example, by collecting further monitoring data. In the following, one example is presented for Categories (b), (c), and (d).

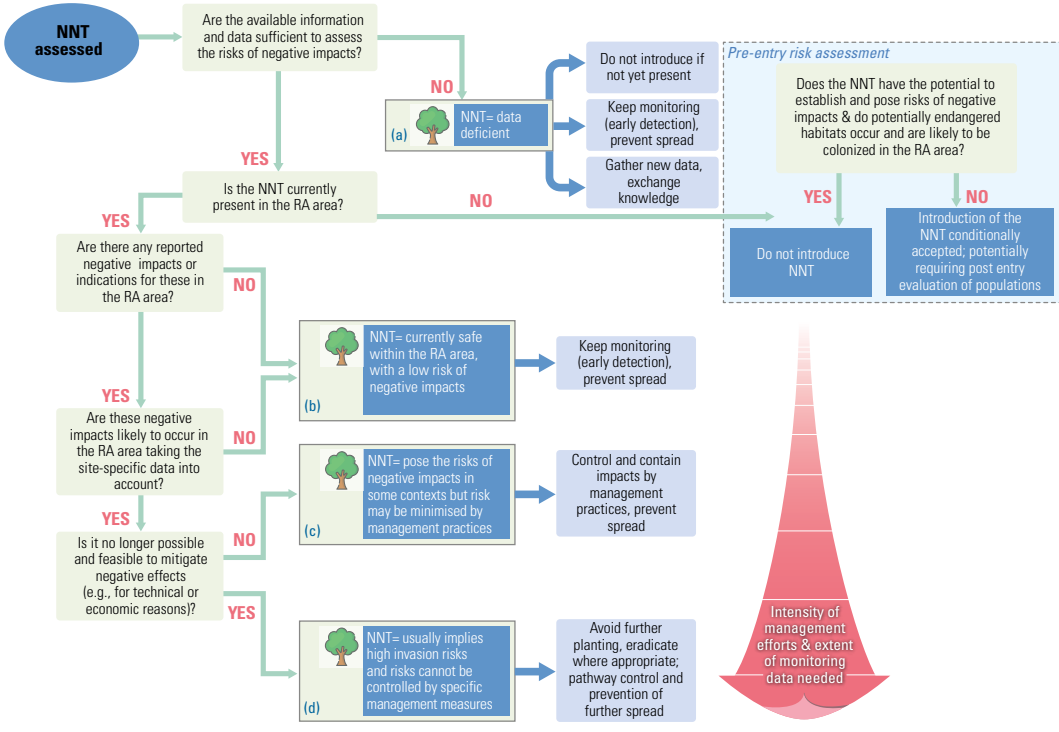

Figure 2: *Decision tree demonstrating practical application of the SSRA (Bindewald et al. 2021a)*

b) Currently safe NNT:

***Cedrus libani* A.Rich (Lebanon cedar)**

The Mediterranean Lebanon cedar, which has seen only little use in forestry in the Alpine space so far, could gain importance in the future as a climatically suitable forest tree species. It is considered a promising species that can tolerate relatively cold winters and persistent summer droughts and is therefore discussed as an alternative to the Norway spruce (*Picea abies* (L.) H.Karst.) (Messinger et al., 2015). However, its high demand for light may be a limitation for its successful establishment when mixed with shade-tolerant species such as silver fir (*Abies alba* L.) and European beech (Messinger et al., 2015; Šeho, 2019). Furthermore, its wide-spreading, horizontal branches indicate that sites with recurring snow may need to be avoided. Due to its scarce occurrence in the Alpine region (except for ornamental plantation, for example around large glacial lakes in northern Italy) and in Central Europe in general, nothing is known as yet about the Lebanon cedar's invasive potential; it is assumed to be low due to the species' moderate competitiveness, however (Šeho 2019). *Cedrus libani* is an example of a NNT involving unknown risks, and there is no need to take urgent measures.

Figure 3: *Lebanon cedar in its native range in Turkey*

Nevertheless, stands and trials in the Alpine space should be carefully monitored for any impacts that may develop, and valuable (semi-)natural woodlands should be excluded from plantations with the species in order to prevent potential negative effects.

c) NNT that pose risks in some environmental contexts but can be controlled through forest management: *Pseudotsuga menziesii* (Mirb.) Franco (Douglas fir)

Because of its high productivity potential, drought tolerance, and excellent wood properties, the Douglas fir is considered an important NNT for addressing the economicw challenges imposed by climate change in the Alpine region (e.g. Wohlgemuth et al., 2021a). However, the species can also pose risks on certain sites. Natural regeneration of Douglas-fir has been reported in several habitat types of high conservation value in south-west Germany, such as rocky outcrops with sparse tree cover and sessile oak forest communities on dry-acidic sites (Fig. 4). In these specific conditions, negative impacts may occur (Bindewald et al., 2021b). Although the Douglas fir has the potential to negatively affect sensitive habitats in the Alpine space, it may be cultivated if tailored management practices can exclude or

Figure 4*: Naturally regenerating Douglas firs in sessile oak forest habitat, south-west Germany.*

minimize such risks (Spellmann et al., 2015). Since Douglas firs are already widely cultivated and have shown significant benefits in forest management under various site conditions, extermination on a national scale is not desirable. At the same time, however, control of the species' spread in high-value conservation areas is necessary. To effectively allocate conservation resources, management should focus on endangered areas for priority actions such as eradication or prevention of wildings. Since natural regeneration of *Pseudotsuga menziesii* has only been reported in a small proportion of protected forest habitats, it is still possible to remove the species from such areas (Bindewald et al., 2021). Due to its inability to coppice, the Douglas fir can be controlled

Figure 5: *Naturally regenerating black cherry in pedunculate oak–hornbeam forest, south-west Germany.*

with relatively little effort by way of stem removal in adult trees and the cutting of seedlings. In addition, there are no European congeneric tree species present that could potentially hybridize with Douglas firs. Cultivation is therefore expected to be unproblematic in areas where stands do not present a threat to native biodiversity; it should nevertheless be restricted in and near susceptible areas, however. In order to prevent possible risks to biodiversity on the cultivation sites, Douglas firs should only be used in mixtures with native tree species (Wohlgemuth et al., 2021b).

d) NNT expected to pose high risks and be difficult to control: *Prunus serotina* Ehrh. (black cherry)

The black cherry poses risks to a range of different ecosystems in the Alpine space. From a nature conservation perspective, establishment of the species in semi-natural habitats such as grasslands, dunes, wetlands, riparian or open forests is particularly problematic (Fig. 5) (Annighöfer et al., 2012). On these sites, established black cherry populations can have negative effects on the structure and composition of native plant communities and soil conditions. The black cherry can also cause problems in forestry when it dominates the understorey in managed forests and hampers the regeneration of desired native tree species (Annighöfer et al., 2012). However, the species is widespread and abundant across a range of ecosystems in the Alpine space, and complete eradication in the entire region is therefore no longer feasible. Moreover, long-distance dispersal by birds makes it difficult to control its spread and thus to implement effective buffer zones. In addition, black cherry trees resprout intensively after disturbances, making it challenging to get rid of the species, at least in the short term. If forest succession is acceptable as a strategic option, forest managers can underplant black cherry with shade-tolerant native tree species to suppress regeneration in the long term (Nyssen et al., 2016). Measures must therefore be thoroughly evaluated on a case-by-case basis and should be oriented around the management objective of the site. Nevertheless, to prevent further invasion, the black cherry should no longer be promoted and the

risk of further spread into endangered areas kept as low as possible (Verheyen et al., 2007).

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NON-NATIVE TREE SPECIES IN THE INTERFACE BETWEEN FORESTRY AND NATURE CONSERVATION

Olaf SCHMIDT

Climate change will require forestry to actively adapt the forests. This encompasses the use of more drought-tolerant alternative tree species, including certain non-native tree species (NNT). However, nature conservationists among others are concerned that these "new" tree species may pose a threat to the forest ecosystem.

In particular, alternative tree species are being sought for the climate-sensitive Norway spruce (*Picea abies* Mill.). Especially in areas already experiencing warmer temperatures, climate change appears to be pushing some native tree species to the edge of their capabilities and tolerances. In order to maintain important forest functions, NNT better adapted to predicted future climate conditions will therefore see increased importance in the future. Overall, a mixture of forests – not only in terms of tree species composition but also in terms of stand structure as well as genetic and age diversity – is becoming more and more essential. When growing NNT, risks for forest owners cannot be avoided. These risks include susceptibility to pests, climatic vulnerability, losses in wood quality, and increased potential for invasion. In addition, there may be consequences for forest ecosystems themselves, such as a decline in insect numbers and diversity. Accordingly, forestry opportunities and conservation risks must be carefully weighed against each other.

Nature conservation vs. forestry

Depending on the interests of the involved stakeholders, attitudes toward NNT can vary widely. While foresters and forest owners are pleased with the growth potential, competitive strength, and regeneration potential of some NNT, nature conservationists see the risk of native tree species being displaced or driven back as a result. And while foresters appreciate NNT that regenerate naturally, conservationists perceive this characteristic as a risk in terms of species becoming invasive, spreading from cultivation sites to other areas and subsequently becoming established. Furthermore, there is concern that a lack of mycorrhiza partners and adaptation of native insects to NNT can lead to loss of insect biodiversity and food shortages for insectivorous bird species, amphibians, reptiles, and small mammals. This argument of food shortages owing to a lack of insect species is supported by several studies (Kolb 1996; Kolbe 1995; Gossner 2004). Native insects are not adapted to NNT, especially in the case of tree genera that are not native anywhere close to their introduced range (in Europe, e.g., *Pseudotsuga*, *Tsuga*, *Cedrus*, *Liriodendron*). The forestry industry tends to view this insect decrease as beneficial, as it is generally accompanied by improved tree vitality due to reduced pest damage, whereas conservationists see the loss of diversity and the potential for associated cascading effects: If there is a general decline in insects, pollinators, and natural enemies, predators may also be affected. The insect biomass in forests could thus diminish, as is already happening in open areas – and with it the food base for many higher species.

Impact on animal species

Phytophagous insects

Gossner (2004) compares the occurrence of phytophagous insect species between common oak and red oak as well as between spruce and Douglas fir. Red-listed species occur to a similar extent on Douglas firs as on spruces, but in significantly lower numbers of individuals. From a species conservation perspective, a major increase in Douglas fir cultivation, especially in pure stands, is therefore likely to result in a

decline in endangered insect species.

Comparing the common oak to the red oak, Gossner comes to the following conclusions:

- The biotic communities in red oak crowns can be classified as poor in terms of species diversity and numbers of individuals compared to the common oak.
- The differences are more pronounced in pure stands.
- The red oak hosts a significantly smaller number of endangered insect species and of individuals of such species. Nevertheless, the red oak is not an "ecological desert".

Over a period of three trapping years, a study on weevils, bark beetles, Monotomidae, and rove beetles in stands with and without NNT revealed significant differences (Kolbe 1995). Although beech stands featured the largest numbers of species and individuals, a mixed forest with NNT performed similarly well in terms of species numbers. However, the numbers of individuals were significantly lower for the weevil and bark beetle groups in the mixed forest with NNT than in beech or spruce forests.

One of the most persistent misconceptions concerning the impact of NNT on native biodiversity is the assumption that hybrid poplars (*P.* x *canadensis*) could represent a "food trap" for endangered butterfly species such as the lesser purple emperor (*Apatura ilia*). As early as 1987, Hafner demonstrated that the caterpillars of the lesser purple emperor also use the leaves of the Canadian hybrid poplar (Barsig, 2004). Nevertheless, in nature conservation communities, the assumption of this supposed biotope trap persists to this day.

In recent studies by the Bavarian State Institute for Viticulture and Horticulture (LWG), native tree species were compared to south-eastern European tree species in pairs (common hornbeam and hop-hornbeam, common ash and manna ash, small-leaved lime and silver lime). A total of 804 window traps, 416 yellow panels, and 390 tapping samples were evaluated, with more than 90,000 insect and spider individuals captured on 30 tree individuals over the entire recording period. So far, however, only the captured cicadas and wild bees have been classified down to the species level in this study. For these two groups, no significant differences

in species abundance were found between the non-native and native tree species (Böll et al., 2020). The assessment of the sweet chestnut (*Castanea sativa* Mill.) has likewise changed as a result of recent research. Since the genus *Castanea* is closely related to the genus *Quercus*, it may be assumed that the spectrum of phytophagous and wood-inhabiting insect species for the two genera is very similar.

Flower constant insects

NNT such as the black locust (*Robina pseudoacacia* L.) and horse chestnut (*Aesculus hippocastanum*) are very attractive to flower constant insects such as honeybees and hoverflies. These tree species are therefore often promoted by beekeepers.

Figure 1: *Hoverflies are attracted by different flowers of trees.*

Wood-inhabiting insects

In forests, wood-inhabiting (xylobiont) insects play a major role in biodiversity. Studies of deadwood beetle fauna in Cologne have shown that wood-inhabiting beetles use both native trees and NNT for their development. Only the difference between coniferous and deciduous trees was found to have an influence. Species in the genera *Populus*, *Tilia*, *Ulmus*, and *Acer* were the most prominent, but the non-native genera *Aesculus*, *Sophora*, *Robinia*, and especially *Catalpa* proved to be important habitats for wood-inhabiting beetles as well (Stumpf 1994).

Birdlife

In winter, Douglas fir canopies lack insects and spiders. As a result of this shortage of food, pure Douglas fir stands are hardly colonized by insectivorous bird species such as the winter goldcrest, coal tit, and crested tit (Gossner and Utschick, 2004). Kolb (1996) found poorer reproductive success in stands with NNT than in near-natural forests in the Weinheim mixed forest during breeding biology studies on great tits. This is due to the limited food supply resulting from the lack of insects.

Conclusion

The cultivation of NNT has ecological effects on forests, for example on the native fauna. NNT should therefore only be introduced into Alpine space forests following a thorough risk assessment – and generally not in pure stands, but rather in mixtures with native tree species so as to limit potential negative consequences as much as possible.

If, as predicted, the climate in our latitudes becomes warmer and drier and extreme weather events simultaneously increase, completely different tree species could gain importance in the future. For example, the sweet chestnut (*Castanea sativa*), Turkey oak (*Quercus cerris*), and Hungarian oak (*Quercus frainetto*), which already exhibit good growth performance in some areas of Central Europe, could also help to create suitable forest patterns in a mixture with common and sessile oak, beech, and pine species.

As with many issues in forestry, a differentiated approach is required. It is not a matter of either/or – rather, a strategy of both/and should be pursued. Especially in forests, their longevity and dominant structure means that trees play a decisive role compared to other organisms of the ecosystem. The choice of tree species is therefore particularly crucial, and forest managers need to take the various aspects into account as comprehensively as possible.

In conclusion, it is not necessary to exclude the use of NNT in Alpine space forests in general – however, such use should be monitored objectively and conscientiously, and the possible advantages and disadvantages of NNT cultivation should be evaluated without bias and communicated accurately.

Figure 2: *European mantis (Mantis religiosa) on a leaf of Acer negundo.*

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STAKEHOLDER PERCEPTION OF NON-NATIVE TREES IN THE ALPINE SPACE

Reneema HAZARIKA

Background

Non-native tree species (NNT) have long been a part of sensitive bioclimatic systems such as the European Alpine region. The majority of the NNT in forests were planted for economic purposes – mainly for timber, wood arboriculture, and biomass production in short cycle rotation. Other purposes such as preventing soil erosion, agro-forestry, fuelwood, and drift sand control are also important. In recent years, NNT have attracted attention from scientists and lawmakers as candidates for adapting native forests to climate change (Lindner et al., 2014). While being beneficial on some sites, the same NNT may prove to be invasive on others (Brundu & Richardson, 2016). The risks, benefits, and trade-offs between different ecosystem services therefore need to be thoroughly evaluated before formulating management policies for NNT in the Alpine space.

Stakeholder opinion is a crucial component in this evaluation process. A wide range of stakeholders is involved in the production, management, and consumption of the ecosystem services provided by NNT. Among others, this includes policymakers, forest and urban authorities, forest owners, forest managers, the timber and tree nursery industry, sectorial agencies and NGOs, scientific societies, consumers, and conservationists.

Various factors influence the perception of individuals or groups of people regarding individual non-native species (or certain groups of them) and their impacts as being problematic, beneficial, or in some cases simply irrelevant (Kueffer, 2013). For example, a forest scientist may consider NNT a solution for adapting forests to climate change, while a forest manager may be interested primarily in the market

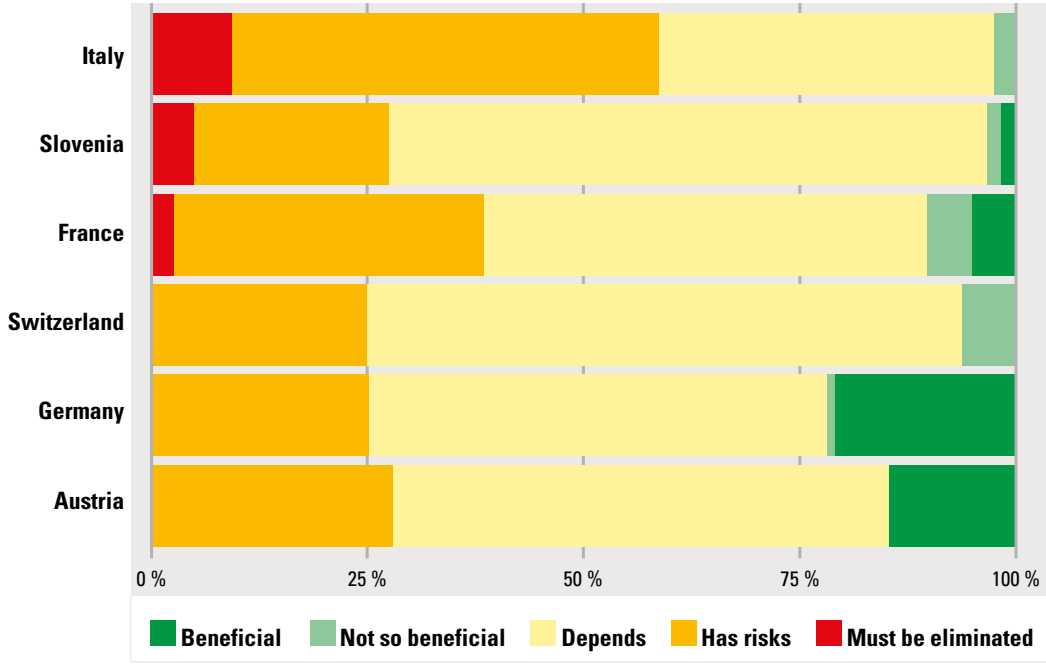

Figure 1: *Perception of the risks and benefits of NNT in the Alpine space. Bar length represents the respective percentage of responses.*

value of NNT timber (Pötzelsberger et al., 2020). Landscape designers may view NNT as exotic additions for ornamentation in urban green spaces, and conservationists may be concerned with the potential risks for native species and ecosystems associated with NNT. On the one hand, negative attitudes towards NNT can complicate management prospects in cases where they also provide benefits. On the other hand, lack of awareness concerning the potential impacts of NNT (and non-native species in general) can lead to ineffective management decisions pertaining to potential invaders (Sharp et al., 2011; Novoa et al., 2017).

Stakeholder perception analysis – ALPTREES project

To the best of our knowledge, stakeholder perception on the risks and benefits of NNT in the Alpine region has hitherto not been sufficiently investigated. In order to develop a "Transnational Guideline for the Use and Management of NNT Species

throughout the Alpine Space", the Interreg – ALPTREES project (2019–2022) therefore conducted a stakeholder survey across the six countries of the Alpine region: Austria, Germany, Slovenia, France, Italy, and Switzerland. The survey was circulated among key forestry stakeholders ranging from foresters, conservationists, and researchers to landscape architects, urban designers, and others.

Stakeholder perception on NNT in the ALPTREES survey

The results of the survey show that many of respondents (Figure 1) believe the risks posed by NNT outweigh their benefits. In addition, most of the respondents stated that benefits and risks depend on the specific context, meaning the specific NNT, site conditions, conservation status of the target forest, degree of human impact, etc. Although the contextual dependency of the risk of invasion by NNT is increasingly recognized by the scientific community, this perception by the various stakeholders may also be attributable to a lack of understanding of the contrasting definitions of NNT on the one hand and invasive non-native species on the other hand. Most NNT do not pose potential or actual risks in the majority of ecosystems in which they occur.

Conclusion

Considerable effort is being made within Europe to manage NNT in the context of their risks and potential invasiveness, while their benefits are still largely under-appreciated in public perception. In the ALPTREES stakeholder survey, it was observed that most respondents perceived potential risks posed by NNT while being uncertain about their potential benefits. This perception is also evident from the incoherent patchwork of policies pertaining to NNT in Europe which views NNT s in the context of invasiveness (Pötzelsberger et al., 2020).

Therefore, such policies address the potential risks of NNTs adequately but fail to realize the benefits of NNTs especially in the context of climate change adaptation. In order to formulate science-based policies for sustainable management of NNT, a cross-sectoral policy approach

involving stakeholders from the areas of nature conservation, industry, forest management, and scientific research is required.

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ECOSYSTEM SERVICES PROVIDED BY NNT FOR CONSIDERATION DURING THE ASSESSMENT OF RISK–BENEFIT TRADEOFF

Patricia DETRY

Taking action to keep forests resilient and maintain the services they provide

Non-native trees (NNT) provide ecosystem services (Figure 1) as part of the forests they exist in. If forests disappear, then the ecosystem services they provide disappear as well; with a view to climate change, this means that more or less profound interventions are necessary.

Forests are essential for society due to the multitude of services they provide (wood production, preservation of soil and water quality, biodiversity, etc.). This is all the more true under the current conditions of climate change, in which they constitute a recognized mitigating factor thanks to the carbon storage and substitution effects of wood.

Several strategic measures for short-term and long-term adaptation exist. They include, among others, the promotion of research on existing and new NNT, new silvicultural models and mixtures, and assisted migration of forest species.

The idea of introducing NNT has often been opposed on the grounds that native species are better able to meet the needs of users and are the only ones capable of constituting sustainable forests. As time goes on, this attitude seems increasingly untenable, however.

Two important aspects need to be considered:

- On one hand is the fact that the present-day forest flora is a result of the history of vegetation over the geological ages and especially the last glaciations, which eliminated many species. There may therefore be other species elsewhere in the world that are capable of thriving and producing value in our regions.

- On the other hand, it is now clear that environmental conditions – and especially climatic conditions – are not immutable and that it is therefore useful or even necessary to search for and test exotic or new species that can advantageously replace local ones in certain areas.

Introducing NNT into existing natural ecosystems involves risks (invasiveness of the species to be introduced, modification of the functioning of the ecosystems, etc.), but all possible avenues must be explored since forests will not be able to adapt sufficiently swiftly to the climate changes we are observing, and NNT can help to develop kinetics faster than those achievable by native species alone.

It is in cities, however, where the challenges of mitigation and adaptation will be the greatest. For these densely populated and built-up territories, global reflection integrating the two mentioned aspects is necessary to identify strategies and urgent measures required to reduce their vulnerability. Among the possible measures, the greening of urban spaces represents a potentially effective course of action and can make the invasive character of non-native species is more easily manageable. In addition, the use of NNT in urban areas has a much lower impact at the greater ecological scale.

Figure 1: *Forest ecosystem services – source: AlpES*

Adaptation to climate change

The most frequently described recommendations accompany natural dynamics or involve active interventions to accelerate the adaptation process:

- Favouring the resilience of stands and natural regeneration, which allows intraspecific variability to be expressed through progressive adaptation to new conditions and promoting the heterogeneity of stands. Since species have different climatic preferences, a stand of varied species can adapt to uncertain future climatic conditions.
- Reducing the density of stands to reduce water consumption.
- Limiting species sensitive to water stress to below 1000 m (e.g., spruce and Scots pine) and planting other more southern or non-native species or provenances in the understorey or in gaps where current regeneration is poorly adapted. Cedar and cypress, for example, can be assets in areas vulnerable to fire.
- Intensifying exploitation, for example by reducing rotation times and exploitable diameters in order to limit exposure to risks and react more quickly in the event of dieback.
- Practising genetic improvement through selection to increase resistance to water stress, late frosts, and pests and diseases; also, taking into account the geographic origin of the seeds and seed collection procedures that are crucial for the adaptation of species.
- Finally, maintaining the connectivity of forests is essential to allow species migration.

Alpine Space Forests

In the Alpine space, 42.5 % of the total land area is covered by forests, with a trend towards increase of the forested area. 6.3 million ha are covered by coniferous forests, 7.2 million ha by broadleaved forests, and 3.2 million ha by mixed forests (Figure 2). Forest resources should not be considered a monolithic entity. Instead, they play a multifaceted role, with complex patterns and relationships among forests and other natural areas, their use, and their interaction with other anthropic systems.

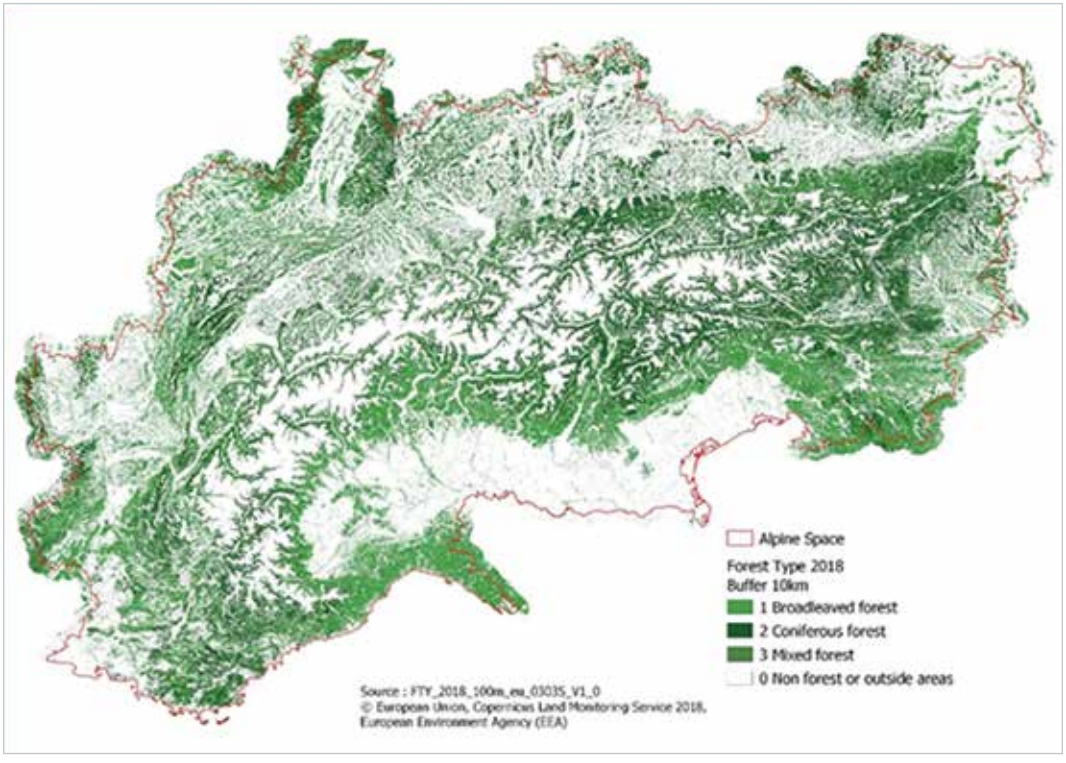

Figure 2: *Overview map of forest cover and forest types in the Alpine region.*

Forest ecosystem services (FES)

Landscape, recreational and cultural services

Forest dieback is transforming forest landscapes in the long term and increasing the risk of accidents (falling branches, etc.) and human health risks (oak and pine processionary caterpillars, etc.), thus justifying the restriction of public access to certain areas.

Biodiversity

Changes in environmental conditions can influence biodiversity by compromising the maintenance of certain species while opening ecological niches for new species. The maintenance of certain species that depend on threatened species will also be compromised in a domino effect.

Water quality

Reduction of forest cover in watersheds or around catchment areas could diminish the purification function of these forests. Dense and healthy forest cover helps to maintain reliable flows of high-quality water downstream.

Safety of human populations, maintenance of natural habitats

Protection against erosion and natural risks including fire. In mountain areas where forests have been used since the end of the 19th century to stabilize land made unstable by over-exploitation and grazing, the risks of torrential floods, block falls, landslides, or avalanches could increase locally in the event of forest regression and dieback.

Wood production, carbon storage, and climate regulation

In the Alpine space, a significant share of carbon emissions are "absorbed" by sequestration during tree growth (biological productivity) in forests. Carbon storage effects are also brought about by the use of long-lasting wood products and the avoidance of emissions by substituting wood for other more energy-intensive materials. Droughts and heat waves coupled with forest fires, wind throws, and outbreaks of insect pests will affect the vitality of forests and thus the capacity to store carbon and offset part of our emissions.

Mapping FES hotspots: A stakeholder's decision support tool

Overlapping the assessment and mapping of multiple ecosystem services will make it possible to identify hotspots of forest ecosystem services across the Alpine space.

Naturally, certain FES are more crucial than others in specific contexts (for example, protection against rockslides and avalanches in recreation areas), and we would have to arbitrarily weight the assessments to obtain useful map results. This process would inform stakeholders where it is most desirable to retain and preserve forests due to the services they provide.

LEGISLATION ON NON-NATIVE SPECIES IN THE ALPINE SPACE

Aleksander MARINŠEK, Anja BINDEWALD, Nicola La PORTA, Reneema HAZARIKA, Patricia DETRY, Frederic BERGER, Katharina LAPIN

The main purposes of legislation pertaining to non-native species are to prevent or regulate their spread into the wild, provide measures for controlling invasive species, and establish lists of species permitted for use as forest reproductive material or other forestry purposes.
Legislation across the countries of the Alpine region is scarce and differs substantially. In some cases, there are also differences in legislation between separate regions within the same country.

1.1 Slovenia

Regulations in the field of forestry
The Slovenian Forests Act includes no provisions directly related to non-native species. The regulations for forest protection (Official Gazette of the Republic of Slovenia, No. 114/2009) regulate, among other things, the conditions for sustainable management and use of forests and maintenance of the biotic balance of the forest ecosystem. A rule on non-native species was amended in 2009. The regulations now state that the establishment or introduction of non-native tree species (NNT) into the forest ecosystem is permitted in accordance with nature conservation regulations, forest reproductive material, and forest management plans. The rules include important provisions on how to proceed when harmful organisms (which may also be non-native species) occur in the forest.

Regulations in the field of nature conservation

Alien or non-native species are primarily regulated by the Nature Conservation Act (ZON - UPB2, Official Gazette No. 96/2004). However, the term "invasive alien species" has so far not been defined in Slovenia. There is also a legal gap concerning confiscation of plants or animals of non-native species that endanger native species, as the implementation law provided for in the Nature Conservation Act has not yet been adopted.

Under the Nature Conservation Act, the establishment of plants and animals of non-native wild species is generally prohibited. It may be permitted by way of exception, however, if the nature conservation impact risk assessment determines that the intervention will not endanger the natural balance or components of biodiversity.

The migration of non-native plants and animals already living in a particular ecosystem must be monitored and controlled. Anyone wishing to carry out resettlement must notify the ministry responsible for nature conservation and submit the findings of an impact assessment with the application. These provisions do not apply to plants used in agricultural and forestry activities, however.

The Decree on Special Protection Areas (Natura 2000 sites) (Official Gazette, RS No. 49, 2004, amendments: 110/2004, 59/2007, 43/2008, 8/2012) sets out the protection policy in Article 7, which includes the following passage: "... (5) Animals and plants of non-native species and genetically modified organisms shall not be introduced into the Natura site." Some measures to control invasive alien species in Natura 2000 sites are also set out in the Natura 2000 Site Management Program (2015–2020).

1.2 Germany

Regulations in the field of forestry

The part of Germany formally belonging to the Alpine region includes the states of Baden-Württemberg and Bavaria. The German Forests Act as well as the forest laws of Baden-Württemberg contain no explicit information on the use of NNT.

In the Bavarian State Forest Act, there is likewise no explicit passage governing the use of NNT. However, selection of site-appropriate tree species for forest regeneration and adequate inclusion of native tree species are recommended. The German Forest Reproduction Act (version of 2003) provides a list of species permitted for use as forest reproductive material, (as of 2019), i.e., *Abies grandis*, *Larix kaempferi*, *Larix* x *eurolepis*, *Picea sitchensis*, *Populus hybrids*, *Pseudotsuga menziesii*, *Quercus rubra*, and *Robinia pseudoacacia*. Other NNT used in Germany are regulated under the EU Directive (Council Directive 1999/105/EC of 22 December 1999), and most of the federal states in Germany recommend forest reproductive material that is not necessarily regulated by the German Forest Reproduction Act.

Regulations in the field of nature conservation

The Federal Agency for Nature Conservation in Germany (BfN 2020) recommends management measures for NNT considered invasive in Germany (Nehring et al., 2013), with a focus on special sites that are priority areas for nature conservation or are usually located in protected areas. For example, it is recommended to remove harmful NNT in such areas by means of adequate maintenance measures. Neighbouring NNT stands should be converted within the framework of silvicultural management measures and in accordance with the precautionary principle. In addition, cultivation near endangered areas should be avoided in the future (BfN 2020). These recommendations are not legally binding for specific NNT, however.

In addition to these general recommendations for all of Germany, specific regulations governing the cultivation of NNT in protected areas also apply. Depending on the protection status or protected area regulations, the cultivation of (potentially) invasive NNT is either possible (e.g., in most landscape protection areas) or subject to restrictions (e.g., in many nature conservation areas and in Natura 2000 areas in case of potential deterioration of the conservation status).

South-west Germany

Guidelines relating to NNT also exist at the regional scale. For example, in the state of Baden-Württemberg in south-west Germany, the monitoring and control of NNT that are or may become invasive is legally embedded in the General Concept for Forest Conservation (ForstBW, 2015). The concept is binding in state-owned forests and stipulates the following measures for dealing with potentially harmful species.

(1) In areas of high nature conservation value, it is prohibited to increase the share of NNT by way of planting or active management, and the overall share of NNT species should be decreased. These areas include rare and valuable (forest) habitats protected by nature conservation laws (§33 Nature Conservation Act BW, §30a Forest Act BW, §30 German Federal Nature Conservation Act, EU Habitats Directive). Specifically, these areas include:

- egally protected habitats, including Natura 2000 habitats,
- nature conservation areas,
- forest reserves,
- regionally rare and valuable areas like semi-natural forest types.

(2) NNT may not be planted or naturally regenerated in the vicinity of protected areas or habitats in which those tree species might become invasive.

(3) A share of 20% NNT in state-owned forests is not to be exceeded.

These guidelines refer to "those alien species which threaten ecosystems", "priority species", or "habitats in which the species could be invasive". No further specification of which habitats are sensitive to NNT and which NNT are problematic is included, with the exception that management approaches relating to the Douglas fir in state forests must involve buffer zones of 300 m around sensitive ecosystem types like near-natural habitats on acidic soils on base-poor and dry sites (birch-oak forests, sessile oak forests, mixed oak forests, and open habitats such as rocky outcrops with sparse tree cover) (ForstBW 2014).

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1.3 France

Regulations regarding non-native tree species in France

In France, the main elements of alien species regulation are seen through the prism of invasive alien species, which are set out in the French Environment Code (and related implementing legislation) and, to a lesser extent, in the French Rural Code.

The French national policy on non-native plant species is the implementation framework of the European Union regulation adopted in October 2014 (EU Regulation No. 1143/2014). This EU regulation on invasive alien species (IAS) prohibits Member States from importing, cultivating, breeding, selling, or releasing into the wild thirty-seven species of plants and animals that threaten biodiversity. The French law of 8 August 2016 for the reconquest of biodiversity, nature, and landscapes includes provisions to apply this European regulation to all French territories (including overseas territories). This policy is shared mainly between the

Ministries of Ecology, Health, and Agriculture. The transversal provisions applicable to invasive alien species in mainland France are now codified in articles L.411-5 to L.411-10 of the Environmental Code.

The ministry in charge of ecology is responsible for developing the national strategy, including implementation of the EU Regulation. The French regulatory framework is thus accompanied by a genuine national strategy enabling coherent action with a medium-term vision and priorities for action. Measures to prevent and control IAS are undertaken with priority against those alien species determined to be of the greatest concern. The strategy prioritizes species at the national level according to the major territorial domains and types of environments impacted or threatened.

The 11 National Botanical Conservatories (NBC) of Metropolitan France are involved in the inventory of natural plant heritage and the identification and conservation of rare and endangered elements of flora, vegetation, and natural and semi-natural habitats. Since 1 January 2017, technical coordination of the NBC has been handled by the new French Biodiversity Office (French public body under the supervision of the ministry in charge of ecology). In this way, invasive plants are inventoried and studied by monitoring their distribution and behaviour within territories so as to identify species that are problematic for the natural heritage and require controlling measures. Each Botanical Conservatory draws up a hierarchical list of invasive alien plant species for the territories it manages in order to characterize the strategy to be adopted by managers for each taxon. Not all exotic species necessarily generate significant impacts on biological diversity, and even less so on human health and the economy. Using these lists, the French biodiversity strategy has five primary thrusts:

- Preventing the introduction and spread of IAS;
- Interventions to manage species and restore ecosystems;
- Improvement and sharing of knowledge;
- Communication, awareness raising, mobilization and training;
- Governance.

At the territorial level, the Regional Directorates for the Environment, Spatial Planning, and Housing (DREAL in French) are responsible for supervising the monitoring of IAS within the framework of the decree of 14 February 2018 on the prevention of the introduction and spread of invasive alien plant species in the metropolitan territory. This decree stipulates that "introduction into the territory, including transit under customs supervision, introduction into the natural environment, possession, transport, peddling, use, exchange, sale, or purchase of live specimens of plant species that are listed in a national list are prohibited throughout metropolitan France at all times." In the sense of the decree, a "living specimen" is defined as "any living plant, any fruiting body, any propagule, or any other form taken by a plant species during its biological cycle".

Some authorizations may be granted by exception, but always under the conditions stipulated by the Environmental Code, and under the condition that the specimens are kept and handled in confinement for the benefit of institutions carrying out:

- Research on these species or their conservation outside their natural environment.
- Activities other than those mentioned above in exceptional cases, for reasons of overriding public interest, including those of a social or economic nature, and after authorization from the European Commission.

To accompany the implementation of this regulation, the Ministry of Ecological Transition and Solidarity has published three technical documents related to the implementation of the regulation on invasive alien species:

1. A technical note on the implementation of IAS control operations, which aims to provide a technical and regulatory framework concerning the conduct of these operations, addresses the possibility of entering private property, and provides various information on the management and fate of waste from management interventions or the financing of operations and compensation.
2. A technical note on the authorization regimes for IAS (mainly detention), which also links up with captive wildlife regulations.

3. A circular on the implementation of border controls to prevent the introduction of IAS from non-EU countries into metropolitan France.

Given the definition of invasive alien species and the threat they pose to biodiversity and associated ecosystem services, all the regulations in the French regulatory codes relating to biodiversity conservation apply to non-native species, and especially to tree species. According to Articles L112-1 and following of the Forestry Code, the conservation of genetic resources and forest biodiversity is recognized as being of general interest; forestry policy falls within the competence of the state and aims to ensure the sustainable management of woodlands and forests under consideration of their economic, ecological, and social functions, with the state ensuring in particular that biological balance and diversity are maintained. According to Article L121-3 of the Forestry Code, woodlands and forests under the forestry regime must meet "in a specific way the needs of the general interest, either by fulfilling the particular obligations provided for by this regime, or by promoting activities such as the reception of the public, the conservation of environments, the consideration of biodiversity, and scientific research."

In France, the use of NNT is strictly supervised and regulated under the national biodiversity preservation strategy, with none of the French codes derogating from this strategy.

In addition, France is a signatory of the Alpine Convention and has ratified its Nature Protection and Landscape Conservation Protocol. Consequently, the French Alpine area benefits from a regulatory framework reinforced by Article 17 of this protocol, which concerns the prohibition of the introduction of species not native to the Alpine region: "The Contracting Parties shall ensure that wild animal and plant species which have never been indigenous to a region in the known past are not introduced there. They may provide for exceptions if the introduction is necessary for certain uses and if it does not have negative effects on nature and the landscape."

1.4 Austria

Forest regulations and processes regarding non-native tree species in Austria

Austria is one of the richest countries in Central Europe in terms of tree species and has a long tradition in sustainable forestry. The land surface covered by forests is 47.9 % (4.02 million ha), well above the EU-wide average. About 88 % of this area (3.53 million ha) consists of managed productive forests (BFW 2019). The Austrian National Forest Inventory reports an average proportion of alien tree species of less than 2 % in Austria (NFI 2009). The alien tree species most commonly occurring in the forest inventory areas during the recent inventory period (2007–2009) were hybrid poplars (*Populus deltoides* × *Populus nigra*) as well as Douglas fir (*Pseudotsuga menziesii*) and black locust (*Robinia pseudoacacia*).

The Austrian Forestry Act of 1975 (Forstgesetz, 1975) provides a list of NNT genera (conifers and broad-leaved trees, see table below) permitted for use as forest reproductive material (FRM) and for forestry purposes (Forestry Act version 2017). These NNT were chosen considering their economic importance and the demand for high-quality timber. Some of them have proven to be of ecological importance or even essential for maintaining the functional balance and biodiversity of European forests in the course of climate change adaptation.

In addition, the management and use of invasive alien species are regulated by the nine individual states' Nature Conservation Acts. In the Styrian Nature Conservation Act 1976/2017 (Steiermärkisches Naturschutzgesetz 2017) on nature protection and care, for example, the invasive species on the blacklist are *Ailanthus altissima*, *Robinia pseudoacacia*, and *Acer negundo*. Supporting these regulations are the strategies and planning concepts of other sectors, for example Austria's Energy Strategy, the National Action Plan on Plant Production Products (pesticides), the Austrian Tourism Strategy, and the Austrian Spatial Development Concept.

Table 1: *List of coniferous and broad-leaved genera of NNT featured in the Austrian Forestry Act of 1975 (version 2017)*
Source: *https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=10010371*

Coniferous	Broad-leaved
Abies	*Acer*
Cedrus	*Ailanthus*
Chamaecyparis	*Betula*
Larix	*Carya*
Metasequoia	*Corylus*
Picea	*Elaeagnus*
Pinus	*Fagus*
Pseudotsuga	*Fraxinus*
Sequoiadendron	*Gleditsia*
Thuja	*Juglans*
Tsuga	*Liriodendron*
	Platanus
	Populus
	Prunus
	Quercus
	Alnus
	Aesculus
	Robinia

Table 2: *List of other relevant regulations concerning invasive/alien species in Austria.*

Regulations in Austria	Relevance
Forestry Seeds Act (Forstliches Vermehrungsgutgesetz) 2002	Governs the marketing and circulation management of FRM as well as imports from and exports to other countries.
Austrian Action Plan on Alien Species (neobiota), (Aktionsplan für invasive gebietsfremde Arten in Österreich) 2004	Focused on activities concerning invasive or potentially invasive species or those with impacts on human health.
Austrian Strategy for Adaptation to Climate Change 2012–2013.	Regarding forestry and biodiversity, the strategy mentions the expectation of a surge in species composition, including the problem of invasive tree species (alien) and the emergence of mutated and new invasive pests causing damage to plants and plant products.
Biodiversity Strategy Austria 2020+ (Biodiversitäts-Strategie Österreich 2020+)	Target 8 of the Biodiversity Strategy Austria 2020+ specifically mentions reducing the negative impact of invasive/alien species.
National Parks Strategy (2010)	Aims to position the 6 national parks as models of conservation in Austria, with management of trees and economic opportunities within the park areas.

Table 3: *Other notable regional regulations for the conservation of forests and natural landscapes in Austria.*

Regional Nature Conservation Acts	Year of Implementation
Viennese Nature protection Act (Wiener Naturschutzgesetz)	1998
Styrian Nature Conservation Act (Steiermärkisches Naturschutzgesetz)	1976
Burgenland Nature Conservation and Landscape Care Act (Burgenländisches Naturschutz und Landschafts-pflegegesetz)	1990
Salzburg Nature protection Law (Salzburger Naturschutzgesetz)	1999
Upper Austria Nature and Landscape Protection Law (OÖ Naturschutz und Landschaftschutzgesetz)	2001
Carinthian Nature Conservation Act (Kärntner Naturschutzgesetz 2002)	2002
Tyrolean Nature Conservation Act (Tiroler Naturgesetz)	2005
Act of Nature Conservation and Landscape Develop-ment of Vorarlberg (Rechtsvorschrift für Gesetz über Naturschutz und Landschaftsentwicklung, Vorarlberg)	2016
Nature conservation Act, Lower Austria (NÖ Naturschutzgesetz)	2000/2016

1.5 Italy

Forestry regulations regarding non-native tree species in the Italian Alpine regions

Regulations in the field of forestry:
Although NNT pose a threat to the environment and ecosystems, there is still no homogeneous national reference framework in Italy, nor any known applications of tools relating to the analysis of environmental damage (pursuant to Legislative Decree No. 152/2006) that would in principle also be applicable to biological invasions. At the national level, the recent Legislative Decree No. 34 of 03/04/2018, "Single text on forests and forestry chains", in implementation of Regulation (EU) No. 1143/2014 of 22/10/2014 and

supplanting all preceding forest legislation, states generically that "the replacement of stands of native forest species with exotic species is forbidden" (Article 7). The state delegates specific actions like the re-naturalization of artificial afforestation and the protection of rare and sporadic native species as well as the protection of old, monumental trees in the regions. Italy is a highly decentralized country with concomitant regional legislation in the areas of forestry as well as NNT. In seven of the northern regions (from west to east: Liguria, Piedmont, Val d'Aosta, Lombardy, Trentino-South Tyrol, Veneto, and Friuli-Venezia Giulia), certain competences relevant to the regulation of NNT may lie exclusively with the regional level of administration. However, only few regional regulations have paid specific attention to the matter of NNT and therefore possess an innovative scope (e.g., L.R. 31/03/2008, No. 10 in the Lombardy region and the ban regulated via a forestry act for the region Friuli-Venezia Giulia, Regional Act No. 9 on forest resources of 23/04/2007).

In addition, there are also some legislative inconsistencies and apparent contradictions among the regional legislation. One controversial example is the use of the black locust in the Lombardy region. This NNT is referred to in several acts and considered from different perspectives. According to EU Regulation No. 1306/2013, farmers can apply for funding for local eradication and control of black locust populations – and as a matter of fact, the species is included in the regional blacklist (Regional Law No. 10/2008, IT17), which includes the commitment to "monitor, contain the expansion, and eradicate (locally)". Several LIFE projects also aim to tackle the spread of the black locust. On the other hand, another legal instrument (Delibera della Giunta regionale Lombardia 20/02/2008 – No. 8/6633) stipulates fines in case of damage to black locust plantations on public and private lands. In addition, the production of black locust honey is financially supported pursuant to Council Regulation (EC) No. 1234/2007, and the honey has even been awarded the Protected Designation of Origin (PDO) (Regulation (EU) No. 1151/2012). Not only in Lombardy but in several other Italian regions as well, monumental black locust trees are protected by dedicated laws. Due to such

conflicting regulations, a considerable degree of uncertainty exists in many regions about what species can in fact be used in forestry, and to what extent. Finally, the existing legislation is insufficient in terms of sanctions.

Regulations in the field of nature conservation:

The national Italian legislation relating to Natura 2000 begins with the Decree of the President of the Republic (DPR) of 8 September 1997, No. 357 and subsequent amendments, entitled "Regulation implementing Directive 92/43/EEC relating to the conservation of natural and semi-natural habitats, as well as wild flora and fauna". Article 12 reads: "Introductions and reintroductions: The Ministry of the Environment and Land Protection, after consulting with the Ministry for Agricultural and Forestry Policies and the National Wildlife Institute, as far as applicable, and the Conference for Reports of permanent agreements between the State, the regions and the autonomous provinces of Trento and Bolzano, establishes with its own decree the guidelines for the reintroduction and repopulation of native species referred to in Annex D of the species listed in Annex I to Directive 79/409/EEC.

Furthermore, the DPR of 12 March 2003, No. 120 and subsequent amendments, entitled "Regulation containing amendments and additions to the decree of the President of the Republic of 8 September 1997, No. 357, concerning the implementation of Directive 92/43/EEC on the conservation of natural and semi-natural habitats, as well as wild flora and fauna" decrees that "the introduction, the reintroduction, and the repopulation in nature of non-native species or populations are forbidden".

Finally, the decree by the Minister of the Environment and the Protection of the Territory and the Sea of 17 October 2007, No. 184, entitled "Uniform minimum criteria for the definition of conservation measures relating to Special Areas of Conservation (SACs) and Special Protection Areas (SPAs)" promotes

1) the creation of arboreal-shrub rows with native species along the borders of cultivated plots;

2) the long-term setting aside of arable land as well as the conversion of poplar land into native broadleaf forests, hay meadows, or wetlands.
Lists and requirements for regional legislation governing specific aspects of nature protection and Natura 2000 areas are also included.

1.6 Switzerland

Switzerland has 26 cantons, administrative subdivisions representing the member states of the Swiss Confederation. Each canton of the Old Swiss Confederacy was a fully sovereign state with its own border controls and legislations. The Swiss Federal Forest Act (Forest Act, ForA) was adopted by the Federal Assembly of the Swiss Confederation in 1993 and includes no specific targets pertaining to IAS. In 2009, Switzerland began a research programme on the adaptation of forests to climate change, which culminated in the revised Federal Forest Act of 2016, the first law to be specifically linked to forest protection in the context of adaptation to climate change. This new law allows for assisted migration of tree species and distant but suitable sources of forest reproductive material. The plan stipulates the rejuvenation of forests, enhancing their genetic adaptive capacity and thereby helping to secure their long-term sustainability.
A report published in 2016 by the Swiss Federal Office for the Environment (FOEN) on non-native species in Switzerland lists over 800 established alien species, of which slightly more than 100 are considered potentially invasive. The National Strategy on Exotic Invasive Species adopted in 2016 states that the Swiss authorities should focus on prevention and on-the-spot eradication to deal with invasive species. In Switzerland, the federal authorities are responsible for the regulation, coordination, and implementation of IAS management as well as for increasing public awareness regarding IAS and informing and educating relevant target groups. But in 2019, a Swiss study on awareness regarding IAS found that only 40% of the participants from the general public were even aware of the term "invasive alien species".

The Forest Europe Resolution M2 adopted in Madrid in 2015 with Switzerland as one of its signatories commits the signatory countries to "increase the work on adaptation of forests and forest management to climate change to prevent and mitigate damage caused by changing conditions at the local and regional scales in order to secure all functions of European forests, including their resilience to natural hazards and protection against human-induced threats, maintaining their productive and protective functions."

Internationally, Switzerland has committed itself to defending native species under the Bern Convention of 1979 (conservation of wildlife and its biotopes), the Emerald Network for Protected Areas, and the UN Convention on Biological Diversity (CBD). Ratified by Switzerland in 1994, the CBD requires member states to compile updated lists of invasive species on their territory and the channels of dissemination. According to the exemption regulation, most of the non-native species present in Switzerland originate from outside the EU/EFTA area. In the absence of a clear basis in community law to prevent the entry and spread of invasive plants and animals, the Member States of the EU Strategy on Invasive Alien Species have adopted a legal basis for imposing unilateral trade restrictions on high-risk species (a blacklist approach of sorts). Switzerland as a non-EU state joined these campaigns (2008–2009) for the prevention of the spread of the North American common ragweed (Ambrosia artemisiifolia), for example. Another quickly spreading NNT species is the windmill palm (Trachycarpus fortunei), which is becoming invasive in many parts of the country. The Swiss Environmental Protection Act (LPAmb, RS 814.01) of 1983 stipulates several principles for the prevention and inhibition of the circulation of exotic and invasive species, but it is still difficult to manage the spread of new invasive alien species outside of forestry and agriculture. For example, there are no legal means to stop private gardeners from importing species found to be invasive in other countries. The sale or export of a few invasive species is forbidden. At the 13th meeting of the Group of Experts on Invasive Alien Species, a standing committee of the Bern Convention, in 2019, Switzerland developed the Swiss National Strategy for IAS Management.

This strategy aims at the targeted information and sensitization of different stakeholder groups as well as the general public. Various departments of the Offices for Waste, Water, Energy, and Air (AWEL) and the Offices for Environment and Energy (AUE) of the different cantons cooperate with the Federal Office for the Environment to manage IAS.

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CASE STUDY ON *JUGLANS NIGRA*

Werner RUHM

The black walnut – demanding but valuable

In the hardwood market, walnut species (walnut, black walnut) have achieved average prices of 500 to 800 €/m³ in Austria in recent years. Individual pieces have been sold for up to 3,000 €/m³.

High quality black walnut wood commands very high prices, with individual veneer logs able to fetch up to 5,000 €/m³ in Germany and 5,000 US $/m³ in the species' native range in the United States.

The black walnut is of particular interest for high-value timber production. In addition to its good growth performance, the timber of the species is of very high quality. The current demand for walnut wood in Austria exceeds local production.

Distribution

The native range of the black walnut (*Juglans nigra*) extends across most of the eastern United States, where it occurs in riparian forests and in good hardwood stands – mostly in troop and group mixtures but rarely in pure stands. In these areas, it can reach heights of up to 46 m with long, branch-free shafts and trunk diameters of up to 1.8 m. In Austria, first experimental cultivations took place in the Danube flood-plain forests at the end of the 19th century. While the black walnut is considered a NNT, the common walnut (*Juglans regia*) is considered native despite having been introduced to the Alpine region from western Asia through Roman trade networks. It is thus classified as an archaeophyte.

General characteristics

The black walnut is a relatively large deciduous tree with a spreading crown and dark green leaflets. It is a light tree species that develops a very deep taproot and is therefore considered very storm-resistant. The fruit (nut) has a yellow-green outer shell with a diameter of 4–6 cm that turns black

after lying on the ground for a long time. The seed kernel is edible. Trees can endure low winter temperatures (up to -40°C depending on origin) without problems but are very sensitive to late frost. The black walnut is very demanding in terms of its stand requirements, needing deep, loose, well-watered and nutrient-rich sites with pH values between 5 and 7. These high demands naturally limit the cultivation options severely. Short floods are well tolerated, while long-term flooding (from 2 to 3 months) leads to death.

Silvicultural characteristics

In very good stands and with appropriate crown size, diameters (DBH) of 60 cm can be easily achieved in 60 to 70 years. For cost reasons and because of the comparatively good growth forms, relatively wide planting clusters are preferred. Planting distances of 4 to 5 m between rows and 3 m within rows (650 to 830 plants per hectare) are a workable compromise to provide enough plants to select the most promising growth carriers (future trees) while keeping planting costs as low as possible. Planting concepts with even fewer individuals – for example 12 m between rows and 3 m within the row (300 individuals per hectare) – require the planting of additional "driftwood". Depending on the location, willow alder, hornbeam, or weeping cherry may be suitable for this purpose. If natural regeneration occurs between the planted individuals in such wide associations, it is very conducive to the desired branch cleaning. Caution is advised, however: As a light tree species, it is very sensitive to lateral pressure. Branching measures are essential for the production of valuable timber in wide associations. Seeding with 1 to 3 nuts per seed site and similar dressings to planting has already been performed successfully in many locations. Thinning should occur early to favour crown growth as a prerequisite for strong growth performance.

For this purpose, at a top height of 8 m, 100 to 120 promising future trees per hectare should be selected, cleared, and thinned. At a top height of 12 to 15 m, 60 to 80 trees are ultimately selected and pruned to their final height, with the crowns consistently freed.

Hazards

Fungal and bacterial infestation are less of a threat than they are for the common walnut. Game browsing tends not to be a major problem either but sweep damage can have a negative impact at lower plant numbers. Depending on plant numbers, fencing or individual protection measures are therefore necessary. Late frosts cause the terminal shoots to freeze back, but the resulting twig formation can be corrected by pruning.

Wood properties

Black walnut wood is one of the most desirable hardwoods in its native region. The sapwood is whitish to light brown, the heartwood chocolate to purplish brown. The wood in general is hard and heavy yet elastic, shrinks only moderately and can be worked well with tools, but is not resistant to fungus and insect attack without impregnation. It is comparable to the wood of the common walnut and therefore very valuable, being frequently used for face veneers, furniture, panelling, parquet, and as a special wood for turning and carving.

INCLUSION OF NNT IN FOREST AND NATURA 2000 MANAGEMENT PROCESS IN LOWER SUSA VALLEY (PIEDMONT – ITALY) – AN ITALIAN ALPTREES CASE STUDY

Sonia ABLUTON, Paolo VARESE

Location: Turin province

Implementation: LAMORO Development Agency in cooperation with the general public and private stakeholders in the territorial reference area.

Aim: To find appropriate references on the inclusion of NNT in forest management programme/planning documents in force or in the process of being approved, and in particular in the following documents:

- The Forest Management Plan (Piano Aziendale Forestale – PFA) of the municipalities of Almese and Casellette;
- The management plan of the Natura 2000 site "IT1110081 – Monte Musinè and Caselette Lakes".

The pilot action was carried out in Val di Susa (Susa Valley) (Figure 1), a valley in the Metropolitan City of Turin, Piedmont region. The valley is located between the Graian Alps in the north and the Cottian Alps in the south and is one of the longest valleys in the Italian Alps, extending over 50 kilometres from the French border to the outskirts of Turin. It has long served as a transit route connecting the plain with the Alpine passes to France. The land offers a rich heritage of art, alpine culture, and natural mountain and forest beauty, along with a culinary heritage based on ancient recipes and natural products. More precisely, the

Figure 1: *Location of Val di Susa in the Alpine space.*

pilot area is located within the territory of the union of mountain municipalities called "Unione Montana Valle Susa" (Susa Valley Mountain Union) with a total population of around 68,000.

In the past, there has been no real management of non-native trees (NNT) in the area. Thinning as a silvicultural measure has been carried out frequently in pine forests to improve their stability, growth, and protective function. Other interventions carried out in the past were aimed at reducing the risk of fires (e.g., bush clearing). The problem of the invasiveness of certain NNT species is a recent one and has been taken into consideration only after the establishment of the SAC (Special Area of Conservation) belonging to the Natura 2000 network.

The main NNT species present in natural and semi-natural environments in the pilot action territory were planted as part of the reforestations for protective purposes around Mount Musinè between the years 1920 and 1970. They include the following species: eastern white pine (*Pinus strobus*), red oak (*Quercus rubra*), maritime pine (*Pinus pinaster*), Douglas

fir (*Pseudotsuga menziesii*), black locust (*Robinia pseudoacacia*), tree of heaven (*Ailanthus altissima*), black cherry (*Prunus serotina*), Monterey pine (*Pinus radiata*), cypress (*Cupressus sempervirens*), and black pine (*Pinus nigra*). We consider the black pine to be a NNT in the pilot action territory region even though it is native to the Alpine space. Other species such as the Chinese windmill palm (*Trachycarpus fortune*i) present in the surrounding gardens and parks are abundantly renewed in the stands of the lower slopes of the territory. The main problems caused by these species are due to the invasive potential of certain non-native trees (black pine, red oak, tree of heaven) in the natural phytocoenoses of the Natura 2000 area and the massive presence of caterpillars of the pine processionary moth (*Thaumetopoea phytocampa*) on sites frequented by families, hikers, joggers, and cyclists. The dense black pine forests also increase the risk of fire.

The Forest Management Plan is an operational tool required by regional legislation (Piedmont Regional Authority). It is the planning and management tool for silvicultural interventions in forest properties and related works and provides the knowledge elements necessary for the implementation of sustainable forest management.
Two Forest Management Plans envisaged for the municipalities of Almese and Casellette stipulate the gradual replacement of NNT, especially those with higher invasive potential, by way of silvicultural interventions favouring native species. However, the presence of NNT is to be preserved in specific highly frequented sites (e.g., picnic areas) as well as in the educational area of "Pian dei Listelli", where a special guided tour of the woods presenting native and exotic species has recently been established. Finally, many black pine and Scots pine forests provide significant protective functions and will therefore be maintained over time if no evolutionary processes are involved in order to guarantee appropriate soil coverage. The two Forest Management Plans apply only to public properties (municipal and state-owned), not to private forests. The latter are characterized by chestnut coppices and secondary forests in highly fragmented smallholder ownership.

Figure 2: *Quercus rubra stands in Susa Valley, Piedmont region, Italy.*

The management plan of the Natura 2000 site, having assessed the existing planning tools as insufficient for maintaining habitats and species in a satisfactory state of conservation, sets specific objectives with the aim of maintaining or improving those conservation states.

In the pilot action, we involved local and regional stakeholders to share and evaluate existing planning tools with regard to their focus on the management of non-native trees (NNT) with the aim of supporting forest managers as well as private and public stakeholders in their decision-making and management processes.

The goal of the pilot action was to create new knowledge and network the main stakeholders; in particular, it aimed to facilitate the integration between ecological and naturalist data on the one hand and information related to forest management on the other, thereby linking two contexts that are currently not always in tune with each other as closely as possible. Furthermore, given the lack of forest planning in the context of private property, indications were to be provided in collaboration with the local forest information point (P.I.F.) to landowners reached during the dissemination phase in order to better involve them in the management of the area's forest resources.

The methodological approach provided for interdisciplinary research between sylviculture, restoration ecology, and applied mycology. Specific test areas (plots) were identified, and the following aspects determined for each of them:

– typological and structural aspects of the forest stand (from the Forest Management Plan data and the regional forest typology),
– the mycological characterization (mycorrhizal and saprophytic fungus inventory),
– the vegetational classification (phytosociological survey),
– the presence of natural regeneration (of both native and non-native tree species).

The following actions were undertaken in the pilot area:

- Identification of the contexts of natural regeneration (from seed and vegetative) of the NNT *Pinus strobus*, *Pinus nigra*, and *Quercus rubra* within the Natura 2000 site "IT1110081 – Mount Musinè and Caselette Lakes". For this purpose, regional databases and the management documentation relating to other planning documents such as the effective Forest Management Plan were queried and analysed. A framework of 14 plots with site, dendrological, mycological and structural data was prefigured to study forest dynamics in this area. In addition to the forest habitats, the spread of NNT within the terrestrial habitats of conservation interest present within the Natura 2000 site was investigated. *Pinus nigra* in particular seems able to assume a certain importance in the succession towards forest and pre-forest communities. A land survey as well as specific technical training for the local stakeholders were carried out. Numerous stakeholders including forest managers, agronomists, landscape architects, foresters, private owners, and others were involved in this process.
- Preliminary methodological research on the use of fungi as useful bio-indicators in the study of dynamic processes related to climate change as well as competition between native and non-native trees (NNT) for the production of edible mushrooms. For this purpose, a mycological survey was carried out in a restricted territory populated by both NNT and native tree species.

- Identification of market outlets for certain wood assortments mainly related to red oak (*Quercus rubra*) in cooperation with local stakeholders, especially wood craftsmen (turners, carvers, cabinetmakers).
- A communication and citizen science activity was carried out among the students of the State Agricultural Technical Institute G. Dalmasso in Pianezza (TO): Students were involved in citizen science activities supporting the collection of data on NNT, sensitizing them to the issue of the presence and management of alien species through the use of the iNaturalist app.

FORESTRY DIAGNOSIS – A FRENCH ALPTREES CASE STUDY

Frédéric BERGER, Dmitry SCHEPASCHENKO, Andrey KRASOVSKIY, Florian KRAXNER

Introduction of the case study area and background

Six territories (Communauté de Communes du Grésivaudan, Métropole Grenoble Alpes, Communauté du Pays Voironnais, Parc Naturel Régional de Chartreuse, Parc Naturel Régional du Vercors, Saint-Marcellin Vercors Isère Communauté) have committed themselves to an inter-territorial work process, bringing together four of the eight existing forestry strategies in the French department of Isère. Led by the community of municipalities of Le Grésivaudan, the approach networks the political representatives of these territories as well as a wide range of stakeholders in the forestry and energy transition sectors (COFOR AURA 2021).

Located at the heart of the French Alpine region, Le Grésivaudan is an area between the plains and the mountains, extending from the Grenoble conurbation to the boundary with the department of Savoy. In an environment dominated by the Belledonne and Chartreuse massifs, the territory is made up of 43 municipalities with over 100,000 inhabitants, 11,400 ha of agricultural land (17% of the territory), and 42,000 ha of forests (53% of the territory). The forested area of Le Grésivaudan is expanding, while agriculturally used areas are declining to make way for abondened land, housing, or economic activities. A territory recognized for its quality of life, it also aims to preserve its wealth of services, landscapes, social links, and economic and tourism dynamics while facing the current challenges generated, among other things, by the impacts of climate change and the desire to optimize nature-based solutions (Le Grésivaudan, 2019).

Objective and description of the planned forestry diagnosis

The issue shared by the six territories concerns the potential of their forestry and wood sector by 2030 in the context of the energy transition under the "Forest Horizon 2030" programme for positive energy territories. The mission of positive energy territories is to establish a new energy landscape combining the values of autonomy and solidarity and applying the principle of active subsidiarity. A positive energy territory aims to reduce its energy needs as much as possible through energy sobriety and efficiency while meeting the residual demand with local renewable energy ("100% renewable and more"). Achievement of the energy transition represents the primary purpose of the positive energy territory: It responds to the fundamental issues of climate change and the depletion of fossil resources as well as reducing major natural and industrial risks on a territorial scale. The concept of the positive energy territory is innovative in that it represents a specific positioning that does not compete with existing initiatives, tools, methodologies, and the like, but instead intends to add value to them.

The aim of this territorial strategy is not to redesign the functioning of the wood sector. It is based on the many shared concerns relating to the sector, like the development of local resources, enhancement of the territory's professional skills, regrouping of plots of land, etc. The question of developing the non-marketable services provided by forests (climatic services, protection against natural risks, recreational functions, etc.), on the other hand, is new for these territories. Once the diagnosis and stakeholder consultation phase has been completed, strategic guidelines and a roadmap for the "Forest Horizon 2030" programme can be drawn up and its implementation initiated.

Description of methods

The forestry diagnosis for the study area includes the following three main actions:

1. Assessment and mapping of forest ecosystem services: protection, production, recreation, climate, landscape.
2. Evaluation and mapping of the likely consequences of climate change for forest ecosystems: changes in the composition of forest species and their spatial distribution, ecosystem resilience, and increased biotic and abiotic risks.
3. Analysis of the functioning and economic weight of the wood sector: management methods, volumes of wood available/accessible/exploited/sawn, etc.

From this diagnosis, the important forestry topics and challenges affecting the territory will be identified, serving as a basis for the elaboration of a political strategy for the territory by developing an action plan around four axes:

1. Promoting multifunctional forest management.
2. Ensuring the sustainability of forest resources and improving the mobilization of local wood resources.
3. Developing the potential of the local wood sector to support the energy transition.
4. Enhancing and promoting transmission of and exchange on forestry culture.

The main challenge currently identified for the forests of the Le Grésivaudan area concerns their development with regard to global warming and the threat the latter poses to the survival of certain species as well as to the development of forests' economic potential via the wood energy sector. Beyond the economic dimension, agriculture and forestry play a major role in maintaining the quality of the environment and landscapes. These aspects must be recognized as a "common good" for the benefit of everyone.

In this context, the work carried out within the framework of the ALPTREES project has made it possible to provide initial factual data for 3 different forest assessments:

1. The projected evolution (suitability) of three relevant tree species and their spatial distribution under the

constraints of climate change (Intergovernmental Panel on Climate Change, scenarios RCP4.5 and 8.5) (Fig. 1-3).
2. The forest ecosystem service of protection against rockfall risk (description of the models in Toe et al., 2019).
3. The evolutionary trend of exposure to the risk of forest fires (using the methodology developed by Dupire et al., 2017).

Please note that the focus of this ALPTREES handbook chapter has been placed on assessment #1) – tree species suitability under climate change.

Outlook: Tree species suitability modelling for forestry diagnosis under "Forest Horizon 2030"

A novel and innovative modelling methodology combining crowdsourced information and data from ground measurements developed within the ALPTREES project is used as a basis for this forward-looking spatial analysis to determine the suitability of certain tree species for the study area under climate change conditions. A global map with species occurrences from the ALPTREES crowdsourcing and citizens science platform within the iNaturalist online app (available from https://www.inaturalist.org. Accessed on May 15, 2021) combined with data from the National Forest Inventories (NFI) for Germany and Slovenia was used. Furthermore, the future projections are based on the IPCC's RCP scenarios generated by the HADGEM2-ES model (Jacob et al., 2014). The modelling was performed for the entire Alpine space, and a zoomed-in map section of the study area is shown in Fig. 1-3. In order to identify a wider range of potentially suitable tree species for the Le Grésivaudan area, a mixture of native Norway spruce (*Picea abies*) and non-native Douglas fir (*Pseudotsuga menziesii*)and black locust(*Robinia pseudoacacia*) forest tree species was assessed.

Initial modelling results for the Le Grésivaudan case study indicate that the current climate of the territory would also be appropriate for the ecological requirements of the Douglas fir (Fig. 2) and, with some limitations, the Norway spruce (Fig. 1). Considering the expected climatic conditions under various IPCC scenarios, the environmental conditions would remain suitable for the Norway spruce

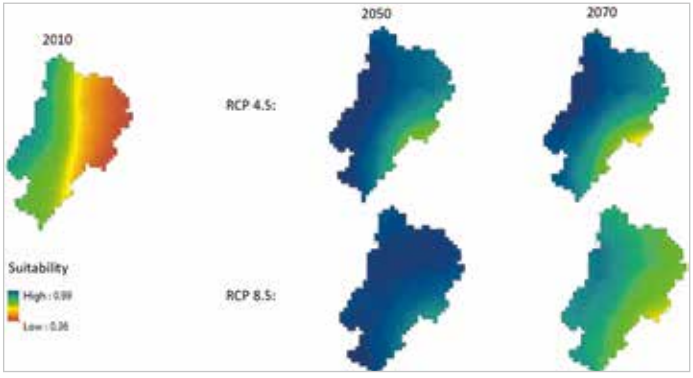

Figure 1: *Norway spruce environmental suitability mapping in the Le Grésivaudan territory, current and future projections according to IPCC scenarios RCP4.5 and RCP8.5 at 2050 and 2070 horizons (modelling by IIASA 2021).*

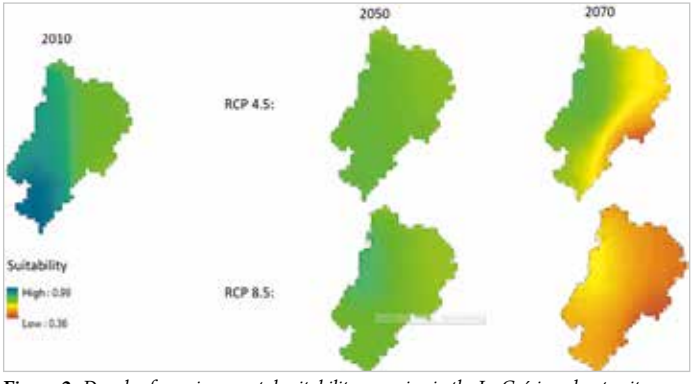

Figure 2: *Douglas fir environmental suitability mapping in the Le Grésivaudan territory, current and future projections according to IPCC scenarios RCP4.5 and RCP8.5 at 2050 and 2070 horizons (modelling by IIASA 2021).*

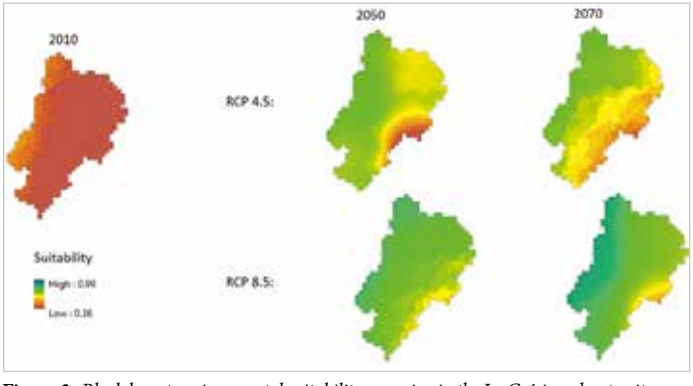

Figure 3: *Black locust environmental suitability mapping in the Le Grésivaudan territory, current and future projections according to IPCC scenarios RCP4.5 and RCP8.5 at 2050 and 2070 horizons (modelling by IIASA 2021).*

(Fig. 1) and black locust (Fig. 3) while providing clear disadvantages for the Douglas fir (Fig. 2).

These preliminary insights into the environmental suitability of native and non-native forest tree species will help to optimize local decision-making. Indeed, one of the Options initially considered was to favour the introduction of the Douglas fir. Based on the results derived from the ALPTREES species suitability simulations under various climate change scenarios, however, this species appears not to be well adapted to the probable future climatic conditions of the territory. On the other hand, species such as the black locust appear to be much better adapted to the local conditions under climate change, and there may be merit in developing a specific sector for them.

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SELECTED NON-NATIVE TREES IN THE FOREST AREA OF THE ALPINE SPACE

Fraxinus pennsylvanica MARSHALL

Green ash

pensilvanski jesen

Rotesche

Frêne rouge

Frassino della Pensilvania

Main characteristics:

- Has a wide physiological amplitude and broad natural distribution range in North America.
- Achieves its highest regeneration potential and best growth in riparian forests.
- Experts do not recommend planting it in Europe due to its invasiveness and pest threat.

Management and use in Alpine space forests

Without any measures to support the growth of *F. pennsylvanica*, it cannot compete with other trees with longer growth periods. It has been successfully planted on heavy and wet sites where no native species can endure the long-lasting flooding events without damage. It can be used as a pioneer for restoration purposes.

Pests and diseases

The emerald ash borer (*Agrilus planipennis*), which is native to Asia, affects all *Fraxinus* species, and the green ash is especially susceptible. There are no reports of the emerald ash borer being active in Europe yet. Ash dieback caused by the pathogen *Hymenoscyphus fraxineus* may be a threat in the future. The species is also prone to abiotic damages like late frosts and stem breakage due to snow and ice.

Invasiveness and risks

The green ash has a high potential for regeneration and the capability to reproduce vegetatively. It spreads actively through riparian forest ecosystems, settling on sites where native tree species cannot cope with long-lasting flooding. Hydrochory offers the possibility to spread samaras over several kilometres.

Timber quality

Green ash timber is known for its stability, hardness, high impact resistance, and extraordinary deflection characteristics. These are excellent properties for use in items like tool handles and sports equipment (baseball bats). However, green ash stands are generally not considered to be able to produce large volumes of valuable timber. The heartwood is classified as perishable and possesses little resistance to rot. The wood is easily processable with hand and machine tools and reacts well to steam bending.

Management and prevention if invasive

Green ash trees should not be planted outside of urban areas. When eradication is intended, mechanical or mechanical-chemical countermeasures need to be planned and executed over a longer period to be effective. Complete removal of the green ash from optimal sites should be considered unrealistic. Effective measures include mechanical girdling (old trees), cutting down of infrequently distributed trees, combatting of seed banks, biological methods (promoting the growth of other tree species, removing specimens close to water), and maintaining distance to protected areas.

Expert opinion

The invasive potential is very high along waters and in riparian vegetation, especially in hardwood-dominated alluvial forests.

Juglans nigra L.

Black walnut

črni oreh

Schwarznuss

noyer noir

noce nero americano

Main characteristics:

- Native to the eastern and midwestern USA, where it is an economically and ecologically important species.
- Imported to Europe for ornamental purposes, but nowadays also cultivated for timber production.
- Can tolerate moderate drought and temperatures down to -30 °C.
- Grows faster than *Juglans regia* and is very resistant to diseases and pests.

Management and use in Alpine space forests

There is currently no comprehensive summary of the silviculture, productivity, and management of the black walnut in Europe that could be used to inform its future role in different countries. The exclusive goal of its culture is the production of top-quality wood for high-end uses. *Juglans nigra* is regenerated by planting or direct seeding on bare land, in monocultures and mixed stands. Management of stands of black walnut, with a rotation period of up to 80 years and the aim of producing valuable wood, includes weeding (mandatory), cleaning and respacing (in dense stands), thinning (mostly from above), and high and formative pruning (mandatory).

Pests and diseases

In Europe, the black walnut is considered to suffer very little from insect outbreaks compared to the USA. However, the thousand cankers disease threatens the species in America as well as Europe. In the black walnut's native area, it has the potential to cause tree decline and mortality. It was discovered in Italy in 2013 and is spreading towards Slovenia. The common walnut (*Juglans regia*) has a moderate sensitivity to this disease. Inonotus hyspidus can cause white rot of the wood, and white-berried mistletoe and yellow mistletoe can infest the crowns of *Juglans nigra*. The back walnut is also sensitive to root collar decay caused by the fungus *Phytophthora cactorum*.

Invasiveness and risks

There is no invasiveness data available.

Timber quality

The black walnut is valued chiefly for its wood, which is heavy, strong, and durable. It is normally straight-grained and is easily workable with hand and machine tools. When finished, the wood has a smooth, elegant surface and an attractive grain pattern. Nevertheless, black walnut wood is slightly less appreciated than that of the common walnut, and it is therefore used chiefly for veneer and other carpentry products in Europe.

Management and prevention if invasive

This species is currently considered non-invasive.

Expert opinion

The black walnut is an economically very interesting species; however, it should be planted somewhat protected from the wind, as it tolerates cold storms poorly. Since it is not very susceptible to browsing and due to the recommended low plant numbers, fence protection can be dispensed with.

Larix kaempferi (LAMB.) CARR.

Japanese larch

japonski macesen

Japanische Lärche

mélèze du Japon

larice giappone

Main characteristics:

- Native to a small mountain region in the central part of Honshu Island, Japan.
- Introduced to Europe in 1834.
- Has good quality wood.
- Fast-growing species, resistant to wind and polluted air.

Management and use in Alpine space forests

Variation between Japanese larch specimens is not related to geography as it is in the European larch. The growth behaviour of a provenance in a certain area will not necessarily be the same under different conditions. Variation in the Japanese larch is random, and each provenance is a story of its own. Seed production for improved European, Japanese, and hybrid larches is often restricted by irregular flowering, frost damage, and low seed count per cone. Several experiments have shown promise for stimulating larch flowering (precocious and early) through treatments of fertilization, root pruning, girdling, strangulation, mulching, and application of gibberellins.

Japanese larch growth rates appear to be particularly sensitive to stand density variations. Pauwels et al. (2007) recommend lower stand densities for larches than for Norway spruce and Douglas fir.

Pests and diseases

Compared to the European larch, it is more resistant to larch canker and larch moth. The pathogen *Phytophthora ramorum* was responsible for tree death in a *Larix kaempferi* plantation in Great Britain.

Needle cast causes considerable growth losses in Japan. *Lasioma melania*, the larch cone fly, is one of the most dangerous pest species affecting larches in Eurasia and is well-established in Western Europe today. *Armillaria ostoyae* is a root disease found in South Korea.

Invasiveness and risks

No data on invasiveness and risks found.

Timber quality

Larix kaempferi has good quality wood, which is why the species is still planted in western and north-western Europe. The wood has been used extensively for pulp, especially in northern Europe and Russia. It is also used for various other purposes such as bridges, carpentry, engineering structures, fences, flooring, and heavy and light construction.

Management and prevention if invasive

This species is currently considered non-invasive.

Expert opinion

The Japanese larch is widely used for forestry and will continue to be a key species unless affected by a new pest or disease or adversely affected by climate change.

Liriodendron tulipifera L.

Tuliptree

navadni tulipanovec

Tulpenbaum

Tulipier de Virginie

L'albero dei tulipani

Main characteristics:

- Native to North America.
- Grows up to 40–60 m in height.
- Individuals can live up to 300 years.
- Cultivated in Europe since 1663.

Management and use in Alpine space forests

Forestry experiments have shown that *Liriodendron tulipifera* fits perfectly into European forest communities, with mixtures with coniferous as well as hardwood species possible. It is best used in mixtures with other light-demanding hardwoods. Its rapid growth during youth and high frost hardiness as well as its general health and resistance to pests and fungi speak for the cultivation of this species. The tuliptree can grow under a canopy for up to 3 years, after which the trees begin to need more space. Good protection against browsing is necessary, as the leaves are eaten by game very quickly. *Liriodendron tulipifera* represents a suitable alternative on ash sites and can play an important role in the adaptation of forests to climate change in the future.

Pests and diseases

So far, no specific pests or diseases are known. Since the genus *Liriodendron* comprises only two species, the introduction of genus-specific pests is unlikely. Problems may occasionally arise from infestation with fungi from the genera *Botryosphaeria*, *Armillaria*, and *Verticillium*, from wilt, mildew, and canker, and from various pests such as aphids and scale insects. In addition, mice and rabbits may cause damage to tuliptree bark, buds, and seedlings. Young shoots are often browsed by game, and abiotic influences such as late frost, snow breakage, snow pressure, and soil compaction affect the species as well.

Invasiveness and risks

The species has not yet been classified as invasive and its potential for invasiveness is considered low. Previous experience indicates that integration into natural, indigenous forest communities is possible without problems. However, further observation is necessary.

Timber quality

Tuliptree wood is light, plain, and features a shiny surface and homogeneous grain. It has a wide, cream-coloured to light yellowish or grey-white sapwood (4–15 cm) and an optional yellowish to olive-green heartwood. The pores are scattered. The wood is soft and easy to work with and is used for furniture production, wall and ceiling coverings, musical instruments, turnery, model making for sculptures, and in the paper industry.

Management and prevention if invasive

This species is currently considered non-invasive.

Expert opinion

Liriodendron tulipifera has great potential for forestry use in Central Europe. It exhibits very good growth behaviour and is non-invasive. There are some 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 need to be protected from late frosts and game browsing after afforestation of exposed areas. Natural reproduction is problematic, as 70% of the seeds are infertile. The tuliptree 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 may occasionally infest it. The wood is easily workable and suitable for the furniture industry as well as for interior finishing and insulation, as it is very large-pored. Its suitability for urban areas is limited, as it forms an extensive root system and does not tolerate compressed soil. It can be planted well in large parks and gardens, however.

Pseudotsuga menziesii (MIRB.) FRANCO

Douglas fir

navadna ameriška duglazija

Douglasie

Douglas bleu

Abete di Douglas

Main characteristics:

- The economically most important non-native tree species in European forests.
- Valued for its high growth potential and favourable wood properties.
- Increasingly discussed as a suitable alternative tree species for maintaining a high level of productivity in forests under future climate change conditions.

Management and use in Alpine space forests

The Douglas fir is widely distributed across European forests and considered to be among the most productive conifers. Based on long-term experiences from provenance trials and silvicultural systems, this species is considered worth cultivating, in part because of its perceived capacity to adapt to future climatic conditions. Nevertheless, cultivating pure plantations on large areas should be avoided, and selecting provenances adapted to local conditions is recommended. Planting of no more than 1,000 to 2,000 saplings per hectare and regular removal of major competitors is advised to optimize the volume and quality of timber production. Pruning is a common silvicultural activity to improve wood quality. Artificial regeneration is preferred, but natural establishment of seedlings under overstorey canopy cover is increasing, particularly within the concept of "near-natural" forest management. Douglas fir stands with long production times are susceptible to storm damage, since large target diameters are associated with tall stands. Cultivation of Douglas firs is increasingly advised as admixture to native tree species so as to increase biodiversity and thus improve the resistance and resilience of forest stands to global environmental change.

Pests and diseases

Douglas fir needles are affected by two fungi, *Phaeocryptopus gaeumannii* (Rohde) Petr. and *Rhadocline pseudotsugae* H. Sydow. Both cause needle cast and a significant reduction in tree growth. Infection with *P. gaeumannii* results in a yellowing of foliage and growth decrease. At present, the insect known as Douglas fir seed chalcid (*Megastigmus spermotrophus* Wachtl), which is presumably co-introduced with host seeds, is considered the primary seed pest in Douglas fir seed plantations. Attacks of *Diplodia sapinea* have so far been limited by the absence of a vector able to transmit the fungus from pines to Douglas firs. This may change with the introduction of the seed bug *Leptoglossus occidentalis*, however, which has been shown to be a reliable vector for *D. sapinea*. Root rot caused by *Heterobasidion* spp. is also noticeable. Tree susceptibility varies depending to the type of forest, with damage mostly associated with *H. annosum* s.s.

Invasiveness and risks

The Douglas fir has frequently been reported as (potentially) invasive in several countries across Central Europe. There is a higher risk of establishment in more open habitats on drier and acidic soils, such as in oak forest communities, since the Douglas fir is less affected by other competitive tree species. Particularly within these forest types, it may have detrimental impacts when it outcompetes native species or alters ecosystem functioning. So far, the full extent of the current or future risks posed to native biodiversity in Europe by *Pseudotsuga menziesii* is highly uncertain. A variety of studies has analysed its interaction with native biota, but the results are not consistent and occasionally contradictory. There appears to be a shift in species composition and species dominance towards generalists rather than specialists in Douglas fir stands. The indirect effects on soil chemistry seem to be similar to those of native coniferous species.

Timber quality

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).

Management and prevention if invasive

The designation of buffer zones around susceptible habitats has been suggested to prevent any detrimental effects. Buffers of at least 300 m are mandatory, but 1–2 km would be preferable. Such buffers should prevent further spread into sensitive areas. Where necessary, forest management can decrease the establishment and spread potential by planting competitive native tree species and removing single trees before they produce seeds. Any undesired occurrence can be removed mechanically with little effort since the Douglas fir does not regenerate by regrowth from root material or via coppice shoots. Regular monitoring is recommended to support conservation planning.

Expert opinion

Several experts have pointed out that the Douglas fir is spreading from managed forest stands into neighbouring semi-natural oak forests or even forest reserves. According to the experts, there is a risk that this tree species alters light and soil conditions, thereby changing species composition. Natural establishment in inaccessible places, such as on steep slopes, has already been reported. Where possible, undesired occurrence resulting from natural regeneration should be mechanically removed. Under expected climate change scenarios, the risk of spread and establishment may decrease in the future.

Tsuga canadensis (L.) CARRIÈRE

Canadian hemlock

kanadska čuga

Kanadische Hemlocktanne

Tsuga du Canada

Tsuga canadese

Main characteristics:

- Very important tree species in the riparian ecosystems within its native range (from Quebec to Alabama).
- The species is noted for having the smallest needles and cones in the genus.

Management and use in Alpine space forests

In its native range, the Canadian hemlock rarely forms pure stands, usually growing in the understorey in mixed forests. Its ecological characteristics include a high degree of shade tolerance, which is related to its crown architecture, light saturation properties, and root/shoot development rates at low light levels. *Tsuga canadensis* is one of the most drought-sensitive trees native to eastern North America, possibly because of its shallow root system; large numbers of individuals are regularly destroyed by serious droughts.

Pests and diseases

The survival of Canadian hemlocks in the wild in the eastern United States is conditioned by infestation with the tiny sap-sucking hemlock woolly adelgid (*Adelges tsuga*). Infected trees frequently become greyish-green rather than the usual healthy dark green. In the northern portion of the species' native range, death typically occurs 4 to 10 years after infestation. Trees surviving the direct effects of the insect attack are usually weakened and can die from secondary causes. Controlling *Adelges tsuga* is exceedingly difficult. Hemlock mortality has been linked to a loss of landscape aesthetics, declines in trout habitats, and an increase in safety hazards in public forests.

Invasiveness and risks

This species is currently considered non-invasive.

Timber quality

Similar to fir wood, light and soft with limited durability. Common uses are boxes, pallets, crates, plywood, framing, and other construction purposes.

Management and prevention if invasive

This species is currently considered non-invasive.

Expert opinion

Storms and fires cause damage because of the Canadian hemlock's shallow root system and low-hanging branches. The species is of little economic importance, with its wood mostly used as construction timber, for interior finishing, and for the production of pulp and paper.

Thuja occidentalis L.

Northern white cedar

ameriški klek

Abendländischer Lebensbaum

Thuya occidental

Tuia occidentale

Main characteristics:

- Occurs in all countries associated with the Alpine region.
- Regeneration in its native range is sensitive to competition and game browsing.
- Very sensitive to drought stress.

Management and use in Alpine space forests

The northern white cedar is an evergreen species with a conical shape that requires ample moisture and space to grow. It is not commercially exploited in the forests of the Alpine region. However, it is known from its native distribution area that perennial silvicultural treatments with periodic harvests of low to medium intensity, retention trees or patches, and protection of coarse woody debris are generally suitable for sustaining *Thuja occidentalis* in forests. Regeneration is sensitive to competition and game browsing, and its success depends on soil pH and stand density. Because of its shallow root system, it is also quite susceptible to windthrow.

Pests and diseases

In its native range, the northern white cedar is generally resistant to rot and insects. However, there are some fungi and insects that can cause damage. *Kabatina thujae* is a fungus that causes the death of branches and twigs, and *Armillaria mellea* can affect the species as well. The jewel beetle (*Lamprodila festiva*) has been observed on *Thuja occidentalis* in Romania. This insect has already been recognized as 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), *Thuja occidentalis* has an unknown/low impact. There are no reports of invasiveness.

Timber quality

The timber of the northern white cedar is used for products that are in contact with water or soil, such as fences, posts, and saunas. Other uses include cabin logs, boats (canoes), exterior fittings, wall panelling, musical instruments, and pencils.

Management and prevention if invasive

This species is currently considered non-invasive.

Expert opinion

Because the northern white cedar does not tolerate drought well, it can grow successfully on deep, skeletal, and fresh soils. Like the Douglas fir, it is sensitive to frost, especially when young.

Robinia pseudoacacia L.

Black locust

navadna robinija

Gewöhnliche Robinie

Robinier

Robinia

Main characteristics:

- The most frequent and abundant non-native tree species in Europe.
- A controversial species with positive economic and negative environmental impacts.
- Appreciated for its resistant wood, suitability for afforestation, erosion control, and honey production.
- Ecosystem engineer that poses serious threats to nature conservation in the form of monodominant stands and broad-scale biotic homogenization.

Management and use in Alpine space forests

The black locust is mainly used in pure plantations or mixed stands. Utilization for biomass production in short-rotation energy plantations has become a worldwide trend over the last few decades thanks to its high yields (fast growth rate, high stem density) and nitrogen fixation ability. Planted or spontaneously formed stands are often regenerated by short-rotation management (coppicing). Growing trees from seedlings is relatively simple and cost-effective, but germination must be facilitated by mechanical scarification. Young trees need to be protected from herbaceous competition and browsing pressure. Once established, the black locust does not require active management unless straight trunks for high-quality industrial wood are desired.

Pests and diseases

Phytosanitary problems related to the black locust are still largely unknown in the Alpine space. While mega-herbivores are of minor significance in Europe, the species is also host to a wide range of fungi. In terms of insect pests, the North American black locust gall midge (*Obolodiplosis robiniae*) specific to *Robinia* is spreading rapidly throughout Europe. Insect attacks appear to be confined to parks or ornamental trees and have not been detected in forest stands.

Invasiveness and risks

Arguably the most problematic invasive alien tree species in Europe. Its invasive potential is related to its long tradition (introduced as early as the beginning of the 17th century) and widespread planting owing to its many beneficial characteristics. The black locust's capacity for quick vegetative reproduction via root suckers, its ability to fix atmospheric nitrogen, and a lack of serious natural enemies make it a competitive pioneer species capable of profoundly modifying ecological communities. It benefits from forest disturbances that result in more light and bare soil. Frontal invasions are particularly common on post-fire sites or degraded forestry plantations. It also often acts as an ecosystem engineer, causing changes in soil conditions and light regime that in turn can alter species compositions across various taxa. For example, the litter produced by *Robinia pseudoacacia* is rich in nitrogen and favours the establishment and potential prevalence of *nitrophilous* plant species. Its fast growth and uncontrolled escape from cultivation into species-rich nature reserves and endangered habitats are of considerable concern with regard to biodiversity conservation.

Timber quality

The black locust produces robust water- and rot-resistant wood. In terms of quality and durability, its wood is even better than that of native oak (*Quercus robur*) or chestnut (*Castanea sativa*) species. Historically, it has served as a source of timber for vineyard poles, wine barrels, boats, waterborne construction, roof shingles, and fence posts. These days, its wood is widely used to make furniture, parquet flooring, and garden and playground equipment. It is also a valuable fuelwood.

Management and prevention if invasive

Annual mowing limits the spread of young seedlings with an undeveloped root system. Cutting, debarking, or burning of mature trees without accompanying measures should be avoided, as these mechanical procedures result in strong suckering. They are therefore often combined with chemical treatment. As an early-successional species, *Robinia pseudoacacia* may be controlled by continuous cover forestry measures. It does not tolerate shade and can thus be efficiently suppressed by native tree species. In all cases, it is necessary to regularly monitor the treated plots for several years. Once naturalized, removal is very difficult, costly, and time-consuming due to the black locust's high vitality, exceptional sprouting ability, rapid growth, and abundant seed production and nitrogen fixation, which result in irreversible changes to ecosystems. Overall, as there is currently no efficient and generally applicable method for eradicating this species, action plans for integrated management combining tolerance in selected areas and strict eradication from valuable sites are required. Such a combination of approaches provides the best option for achieving a sustainable coexistence of the black locust with humans and nature.

Expert opinion

The black locust is already widely used in parks and urban areas. It is also very interesting for the stabilization and restoration of bare grounds, where its invasive character is tempered by its short life span.

The species is potentially invasive in disturbed areas, and its multifunctional character means it is already present on many sites. It should not be completely rejected but instead controlled appropriately for wood production in specific areas, as it is not invasive in a matrix of continuous cover forest.

Quercus rubra L.

Northern red oak

rdeči hrast

Rot-Eiche

Chêne rouge d'Amérique

Quercia rossa

Main characteristics:

- First introduced to Europe in the 17th century.
- Valued in forest management for its high growth rate and drought resistance.
- Proven to have considerable negative effects on native biodiversity.

Management and use in Alpine space forests

In forests, the northern red oak is cultivated in mixed stands (e.g., with European beech) for wood production. It is often planted on sites that are also suitable for native oak species and other noble deciduous trees due to their similar ecological requirements. It performs well across a relatively broad range of site conditions, except on calcareous soils with high pH levels. Seedlings are moderately shade-tolerant and able to compete with native species. Regeneration of the northern red oak is limited due to the low-light environment in the understorey of dense stands, seed predation from animals, and deer browsing.

Pests and diseases

In Europe, the northern red oak seems to be less prone to herbivores and fungi than in its native range, where it is grazed by ungulates and insects and infected by *Phytophthora* and oak wilt. In general, the species is less susceptible to pathogens and seed predation than native tree species. On humid sites, however, root rot (infestation with *Armillaria*) is frequently observed. Deer browsing is considered one of the most important limiting factors for natural red oak regeneration.

Invasiveness and risks

The northern red oak is a threat to native species within its introduced range, as it can alter environmental conditions beneath its canopy, especially by decreasing light availability and creating thick litter layers resistant to decomposition. Such conditions can also contribute to biotic homogenization of the understorey vegetation: In monocultures, the understorey vegetation tends to be rather species-poor. The northern red oak has spread into forest areas of high conservation value, where it may pose risks to biodiversity and its natural regeneration is therefore not desired. Many Natura 2000 habitat types in the Alpine biogeographical region are under pressure from biological invasion. The spread of *Quercus rubra* may be facilitated by dryer conditions caused by climate change. Current assessments of its competitive ability and its influence on biodiversity are very divergent, so that further studies are needed.

Timber quality

The northern red 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.

Management and prevention if invasive

To prevent the spread of this species, the establishment of buffer zones of 2 km around more susceptible forest sites (e.g., open, dry, and acidic sites) is recommended. In addition, repeated spring or summer coppicing and soil tillage can limit the spread. Mechanical removal of 1 to 2-year-old regeneration is possible, since the northern red oak does not reproduce via growth from roots. Removal of older trees will inhibit seed production, but sites need to be revisited regularly. Girdling is cheap and feasible for older trees. Chemical treatment is cost-effective but often not viable for environmental reasons. Planting native species (e.g., European beech) instead of NNT should be considered in any case.

Expert opinion

Although the northern red oak is considered one of the promising "alternative" tree species currently under discussion to replace the loss of some native species, consideration should be given to its invasive potential. It is much more tolerant of summer heat than most native tree species. It is also very drought-resistant and often exhibits pioneer behaviour in more extreme sites. In native oak and oak-hornbeam forest communities, *Quercus rubra* tends to displace the natural regeneration of native tree species. It should therefore be introduced only in mixed stands, and managers and forest owners should avoid monocultures. In beech-dominated forests, it is currently always inferior to beech in small-scale and long-term regeneration processes. However, some experts think it may even be able to compete with the European beech.

Abies bornmuelleriana MATTF.

Bornmüller's fir, Turkish fir

Bornmüllerjeva jelka

Bornmüllertanne, Türkische Tanne

Sapin de Bornmüller

Abete di Bornmüller

Main characteristics:

- Hybrid between Nordmann fir (*Abies nordmanniana*) and Greek fir (*Abies cephalonica*).
- Its natural range is Asia Minor in north-western Turkey.
- Important forest tree in its native area due to its rapid growth and high tolerance to late frost.
- Extremely tolerant of heat and drought, great silvicultural potential against the background of global warming.

Management and use in Alpine space forests

Outside of its natural range, the Bornmüller's fir is well suited for enriching maple, oak, Douglas fir, or spruce stands. It can also be mixed with trees such as *Alnus glutinosa*. Because the species is sensitive to drought when young, it is recommended to enrich the seedlings with chaff residue to prevent them from drying out quickly. Single planting should be preferred over nest planting so as not to provoke bark beetle infestation. The failure rate after late frosts is lower than with related species.

Pests and diseases

Hylastes ater, Pityophterus micrographus, and *Rhagium bifasciatum* affect the species in its native area. In Central Europe, no notable pests or diseases are known so far, though there is a possible threat of infestation by the bark beetles *Heterobasidion abietinum* and *Dreyfusia nordmannianae*. Mistletoe infestation by *Arceuthobium oxycedri* or *Viscum album* also occurs. Very susceptible to browsing and damage by red deer and roe deer.

Invasiveness and risks

The species is currently considered non-invasive. However, further cultivation trials are necessary to ensure a comprehensive evaluation.

Timber quality

The wood of the Bornmüller's fir is very similar to that of the silver fir with regard to its appearance and use. It is homogenously whitish in colour, with slight yellow or reddish nuances. It is very easily workable and can be used for handicraft work and as construction timber. The bark, buds, and cones may contain a large amount of highly resinous turpentine. A fine turpentine oil can be distilled from this crude material, and the residue forms a coarse resin named colophony or rosin. Fresh oleoresin is mainly used for pharmaceutical purposes.

Management and prevention if invasive

This species is currently considered non-invasive.

Expert opinion

The economic importance of *Abies bornmuelleriana* will increase over the coming years. The state of Baden-Württemberg (Germany) now permits and even promotes cultivation of the species in forestry. In Germany, the Bornmüller's fir has hardly been used outside of Christmas tree cultivation so far, whereas it is already frequently seen along roads in Italy. In trials, it has exhibited better growth and development results than *Abies alba*. Although it has been struggling with late frosts in recent years, it is recovering better than the Douglas fir and silver fir. It is also very suitable for agroforestry.

Abies cephalonica LOUDON

Greek fir

grška jelka

Griechische Tanne

Sapin de Céphalonie

L'abete di Cefalonia

Main characteristics:

- Monoecious, wind-pollinated, evergreen tree with a well-developed root system.
- Endangered species, with numbers in decline.
- It has been hypothesized that Greek fir forests are showing signs of stress and dieback commonly related to mismanagement in the past, periodic drought, and disease.
- Considered one of the Mediterranean fir species most sensitive to frost.

Management and use in Alpine space forests

Detsis et al. (2016) advise the use of large amounts of seedlings in reforestation projects involving the Greek fir, even in drought-stressed areas. Due to the high costs involved, they recommend shading with jute cloth to improve survival rates on unfavourable plots such as limestone. They discourage planting the species in marginally suitable sites, except to a very limited extent.

Pests and diseases

Various pathogenic fungi (*Heterobasidion annosum*, *Armillaria mellea*, *Armillaria gallica*) affect the Greek fir. *H. annosum* and *A. mellea* were the main causes of mortality in young regeneration in the study area in Greece. Bark beetles (*Phaenops knoteki*, *Pityokteines spinidens*) also play an important role in fir mortality because they infest and kill trees suffering from water deficiency and/or affected by other abiotic and biotic factors. Mistletoe (*Viscum album L.*) is a major stress factor as well, affecting crown density and mortality of firs. The fir budworm (*Choristoneura murinana*) is an important defoliator.

Invasiveness and risks

From the literature, it does not seem that the species is invasive anywhere; on the contrary, it is even considered endangered. There is a lack of data from areas outside its native range, however.

Timber quality

Because of its durable and firm wood, it used to be a highly appreciated and economically important species in Greece (Brus, 2004), but it is nowadays too rare to be of economic significance (Jagodziński et al., 2015).

Management and prevention if invasive

This species is currently considered non-invasive.

Expert opinion

All fir species are evergreen, deep-rooted trees with a straight, columnar trunk. Mediterranean firs are better able to strike out after damage, and the Cilician fir as well as the Greek fir reach the timberline. The sharply pointed needles prick and are very hard, thus providing ideal protection against browsing by game. Because of its drought resistance, the Greek fir would be suitable for timber production in Central Europe, perhaps for cultivation in flat and hilly regions. Black pine sites might be improved with this fast-growing tree species, or with the silver fir at its lowest distribution limit.

Abies grandis (DOUGLAS EX D. DON) LINDLEY

Grand fir

velika jelka

Küstentanne

sapin geant

Abete bianco americano

Main characteristics:

- Introduced to Europe in 1830.
- Does not tolerate drought but can tolerate cold and shade.
- Not a recommended species for planting in cities due to its large dimensions and sensitivity to air pollution.
- Prone to infestation by numerous insects in its native range (western USA).

Management and use in Alpine space forests

Mature tree: *Abies grandis* has excellent self-pruning qualities. Its thin bark, low taper, and narrow crown contribute to the high productivity of the species. Young tree: on warm and water-deficient sites, temporary protection by hardwood nurse trees such as *Alnus rubra* improves the survival rate of planted seedlings. Regeneration: As a moderately shade-tolerant tree, the grand fir can regenerate in intermediate light conditions on shallow and friable forest floors or exposed mineral soil. Such conditions usually occur in the understorey of hardwood stands.

Pests and diseases

In Europe, the grand fir is affected by the bow-legged fir aphid (*Cinara curvipes*), which causes drying of young trees, as well as by K*abatina abietis* Pehl (1993), which attacks needles and causes necrosis of saplings and young trees below 10 years of age (both reported in Slovenia). In its native area, it is attacked by numerous insects including the western spruce budworm (*Choristoneura occidentalis*) and the Douglas fir tussock moth (*Orygia pseudotsugata*), which both cause defoliation, top kill, and mortality, as well as the western balsam bark beetle (*Dryocoetes confuses*), fir engraver (*Scolytus ventralis*), fir cone moth (*Barbara* spp.), fir cone maggots (*Earomyia* spp.), and several seed chalcids.

Invasiveness and risks

Abies grandis is considered to be an invasive species in Great Britain, but it is not invasive in the Alpine space.

Timber quality

The grand fir is an economically important species in its native range. Its soft wood is a valued source of pulp, and it is also harvested as timber despite being weaker and more prone to decay than many other species. It is also used for plywood and has been employed for various rough construction purposes.

Management and prevention if invasive

This species is currently considered non-invasive.

Expert opinion

Underestimated non-native species in Europe in general. Only in recent years has more attention been paid to the grand fir due to its large dimensions and rapid growth. Some experts value it less owing to the allegedly poorer quality of its wood in European sites, but there are no reliable studies on this topic. There is hitherto likewise insufficient research into its impact on sites and its role in the environment. The grand fir is one of the species whose use should be studied more intensively in experimental plantations in the future. Its potential invasiveness has not been an issue in Europe so far.

Abies nordmanniana subsp. *equi-trojani* *(ASCH. & SINT. EX BOISS.) COODE & CULLEN*

Nordmann fir, Caucasian fir

kavkaška jelka

Nordmanntanne, Kaukasustanne

Le sapin de Nordmann

L'abete del Caucaso

Main characteristics:

- Native range in the western Caucasus and south-eastern Anatolia.
- Apart from its use as a Christmas tree, it does not have any significant economic value so far.
- Its silvicultural potential and its superiority over related species have become apparent on experimental plots.
- The species is classified as non-invasive and is not affected by any notable pests or diseases.

Management and use in Alpine space forests

The Nordmann fir is hitherto not considered to be of any significant forestry importance outside of cultivation for Christmas trees and occasional use in parks and gardens. However, various field experiments have proven the great silvicultural potential of the species. It is ideally suited as a mixed tree species for the enrichment of deciduous and hardwood stands. Single planting should be preferred to nest planting so as not to provoke bark beetle infestations. It should not be cultivated on sites prone to late frost or on soils exposed to stagnant water. As the species is sensitive to drought when young, it is recommended to enrich the seedlings with chaff residue.

Pests and diseases

The species is not heavily threatened by pests or diseases in its natural range; only bark beetles (*Morimus verecundus*, *Cryphalus piceae*) and mistletoe infestation (*Viscum album*) can become a problem. After planting, Nordmann firs should be fenced in to protect them from excessive browsing damage.

Invasiveness and risks

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

Timber quality

The wood is soft and resistant to bending. Due to its limited distribution, Nordmann fir wood has no great economic importance from a global perspective. In its natural range, it is mainly used in the pulp and paper industry. The wood is easy to process and is sometimes used in aircraft construction and for musical instruments.

Management and prevention if invasive

This species is currently considered non-invasive.

Expert opinion

The economic importance of the species will increase in the future, and it is a good alternative to the native silver fir and spruce. It has exhibited better growth and development results than *Abies alba* in trials. Specific pests have not been reported so far.

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:

- Intentionally introduced to Europe for horticultural and landscaping purposes.
- Little economic use is made of this species in terms of timber or fuel production.
- Due to its invasiveness, environmental risks appear especially in riparian zones.

Management and use in Alpine space forests

Among the measures used to control this invader in its secondary range, destroying spontaneous seedlings seems preferable; cutting of grown trees is not effective, as they can regrow from stumps. At a local scale, yearly repeated girdling and additional removal of seedlings from the understorey layer has proven to be more effective when applying the girdling to adult as well as sapling individuals.

Pests and diseases

Multiple pests and diseases affect the box elder, of which only some of the most important are mentioned here. *Anoplophora glabripennis* is an invasive long-horned beetle that spreads when infested trees are cut or trimmed and the wood moved. *Eutypella parasitic*a causes maple canker, which was discovered in Slovenia for the first time in 2005. *Inonotus rickii* is a basidiomycete that causes cankers and is very invasive along city boulevards.

Invasiveness and risks

The box elder is considered problematic in many European countries. It is 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.

Timber quality

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.

Management and prevention if invasive

Physical removal of *Acer negundo* and suppression during the phase of young trees with subsequent reforestation with native species. Increasing the proportion of shade-tolerant species as well as increasing the age of competing native species can also represent successful strategies for limiting its spread.

Expert opinion

In contrast to other invasive tree species, which provide commercial value in addition to ornamental uses (e.g., *Robinia pseudoacacia*, *Prunus serotina*), no such uses have been identified for the box elder so far.

Cedrus libani A. RICH.

Lebanon cedar

libanonska cedra

Libanon-Zeder

Cèdre du Liban

Cedro del Libano

Main characteristics:

- Evergreen conifer with a natural range in the Mediterranean mountains of Turkey, Syria, and Lebanon.
- Its timber is durable and can be processed easily.
- Used in the past by the Egyptians for the construction of temples.

Management and use in Alpine space forests

While *Cedrus libani* is not a tree relevant to forestry in the Alpine region, some experimental plots maintained by forest research institutions exist. Afforestation outside the species' natural range has been carried out in Italy and France, and several cultivation and provenance trials were implemented in Switzerland, Germany, France, and Italy, but the available knowledge is still insufficient for silvicultural recommendations. According to the current state of knowledge, the Lebanon cedar grows well in shallow locations on limestone; provenances from Lebanon should be avoided, however, as they are at risk from late frost. Furthermore, indications of an increased risk from wet snow have been reported. A study from Bavaria (Germany) showed good growth potential under Central European climatic conditions.

Pests and diseases

The Lebanon cedar is threatened by *Acleris undulana* (cedar leaf moth), *Parasyndemis cedricola* (Lebanese cedar shoot moth), *Traumatocampa ispartaensis* (cedar processionary moth), and *Thaumetopoea pitocampa* (pine processionary moth). Bark beetles, longhorn beetles, and jewel beetles appear as secondary pests. Planting on moist or compacted soils that are not suitable poses a considerable risk of *Armillaria mellea* infestation. The fungus *Botrytis cinerea* causes *Cedrus libani* needles to turn yellow and die. Furthermore, studies from Lebanon report that *Cephalia tannourinensis* (cedar web-spinning sawfly) negatively affects single tree performance, stand structure, and regeneration.

Invasiveness and risks

No reports on invasiveness. Due to its scarce occurrence in Central Europe, nothing is yet known about the species' invasiveness, but it is assumed that the Lebanon cedar has no invasive potential due to its low competitive strength.

Timber quality

Due to its easily processable and weather-resistant timber, it is still a sought-after tree species today. The hardness and durability of the wood are comparable to teak (*Tectona* sp.) and black locust (*Robinia pseudoacacia*), and it is used for construction, veneer, furniture, or masts. It is easy to polish and varnish and does not warp when drying. The growth rings are wide and there is a large proportion of yellowish to reddish brown heartwood. The sapwood is pale yellow to pale red. The wood also has a very aromatic smell, and its essential oils are used for cosmetic purposes.

Management and prevention if invasive

This species is currently considered non-invasive.

Expert opinion

Cedrus libani is very tolerant to drought, but caution is required as it is sensitive to frost. The timber can be processed very well in joinery and is used for equipment and construction in interior and exterior applications, e.g., for furniture and shipbuilding. It is also suitable as a decorative and carving wood and has a pleasant smell when worked.

Chamaecyparis lawsoniana (A. MURRAY BIS) PARL.

Lawson cypress

Lawsonova pacipresa

Lawsons Scheinzypresse

Cyprès de Lawson

Cipresso di Lawson

Main characteristics:

- Evergreen conifer with native range in the western USA (Oregon and California).
- Has become near threatened in its native range due to an outbreak of the *Phytophthora lateralis* fungus.
- The timber is light, soft, and durable, which makes it very valuable.

Management and use in Alpine space forests

The Lawson cypress occurs in the Alpine space on experimental plots maintained by forest research institutions. It can grow under a forest canopy or as a pioneer in the open. However, silvicultural experience shows that cultivation on open land can lead to bushy growth with extreme twig formation. Its shade tolerance makes it suitable for planting in gaps in stands as well as for underplanting or pre-planting. Interior forest climate can protect it against frost damage, but over-shaded specimens will lose some growth potential. Generally, the growth rate is relatively slow in young trees, but older trees retain their ability to respond to more light and space and can become dominant in old-growth forests.

Pests and diseases

The most serious threat to *Chamaecyparis lawsoniana* is the fungus *Phytophthora lateralis*, which causes root rot and has resulted in the species now being classified as "near threatened" in the USA. In Europe, outbreaks of *P. lateralis* have occurred in north-western France and the UK. Various other fungal pathogens can also result in premature death of the shoot tips. In some cases, bare patches are an indication of infestation with the thuja leaf miner moth *Argyresthia thuiella*. Visible holes in the trunk and dried-out shoots are signs of the thuja bark beetle, which has spread rapidly in Germany within a few years.

Invasiveness and risks

No reference on invasiveness found.

Timber quality

The timber is light, soft, evenly grown, and durable, making it very valuable. It has a fine texture and is straight-grained, easy to work with, and resistant to decay. The wood is suitable for a wide range of applications such as general construction, railway sleepers, doors, toys, and – in the past – arrow shafts and Venetian edging battens.

Management and prevention if invasive

This species is currently considered non-invasive.

Expert opinion

In recent years, the Lawson cypress has seen increasing use in hedges in South Tyrol. The varieties are in high demand and grow very well. Pests and fungal diseases are not known or occur only very sporadically.

Ailanthus altissima (MILL.) SWINGLE

Tree of heaven

veliki pajesen

Götterbaum

ailante, arbre du ciel

Ailanto, Albero del paradiso

Main characteristics:

- Has become invasive on all continents except Antarctica.
- Most abundant in urban habitats and along transportation corridors, but can also invade natural habitats.
- Scientists predict that global warming will further increase the expansion of its range.

Management and use in Alpine space forests

In Europe, the tree of heaven invades riparian forests as well as some mesic and xeric woodlands, preferably in the sub-meridional to meridional zones. The methods used to control it include manual, mechanical, and chemical measures as well as burning, grazing, and biocontrol. It is very difficult to remove once it has established a taproot, and all treatments therefore require subsequent monitoring. So far, a combination of mechanical and chemical treatment appears to yield the best results.

Pests and diseases

Ailanthus altissima has natural defence mechanisms to certain pests due to the chemical composition of its tissues. However, it is palatable to snails and some insects such as the mulberry moth (*Hyphantria cunea*) and ailanthus silk moth (*Samia cynthia*). The latter has spread from China to multiple European countries. Wilt diseases caused by *Verticillium* spp. are regarded as the main cause of mortality.

Invasiveness and risks

The tree of heaven is very prolific and widespread as an invasive species in Europe (25 countries and 54% of the total introduced range). It has become invasive on all continents except Antarctica and affects the environment by acting as an allelopathic species, changing soil conditions as well as the trophic cascade. Young trees grow rapidly, outcompeting many other plant species for light and space. In riparian communities, the presence of *Ailanthus altissima* has been associated with lower plant species richness and phylodiversity.

Timber quality

The wood of *Ailanthus altissima* is light and durable. In Slovenia, it is used to support beans growing in karst areas. It has a low energetic value and combustibility and produces smelly and suffocating smoke, making it unsuitable as firewood.

Management and prevention if invasive

Controlling tree of heaven invasions has proven to be a difficult task. Only chemical treatment of cut stumps shows long-term success, whereas pure mechanical removal is often counterproductive due to the species' extreme resprouting ability. Whether or not targeted control of *Ailanthus altissima* in protected forests is feasible in the long term depends strongly on the individual forest structure and species composition.

Expert opinion

The tree of heaven is one of the most controversial non-native tree species in Europe. It has not only been used in gardens for its beauty but also widely employed for the reforestation of degraded areas. The species was introduced to Europe a long time ago and was planted frequently, both of which are factors promoting invasiveness. Having successfully established itself in harsh environments, it is now recognized as one of the most dangerous invasive species and is believed to have negative impacts on the biodiversity of local ecosystems. However, the tree of heaven rarely invades managed natural forests or cultivated agricultural land, instead spreading mostly to abandoned or uncultivated sites. This species clearly shows how human intervention in natural ecosystems can trigger long-term processes that can become unstoppable after a sudden change in social perspectives and values. For now, *Ailanthus altissima* has only limited use and is considered undesirable by forest owners, but recent research indicates considerable potential for wood and honey production.

Cedrus deodara (ROXB.) G.DON

Himalayan cedar

himalajska cedra

Himalaya-Zeder

cèdre de l'Himalaya

cedro dell'Himalaya

Main characteristics:

- Coniferous tree native to the western Himalayan region (Afghanistan, Pakistan, Nepal, China, and India).
- Usually occurs at higher elevations and is very important for the wood market in India.
- Can reach heights of up to 50 metres in its native range.

Management and use in Alpine space forests

There are some reports of Himalayan cedar stands in the Mediterranean region, but its overall occurrence in Europe is negligible. Experimental plantations in north-western Italy have shown good results regarding economic usage in the shape of short-rotation coppice. After reaching the rotation time of 14 years, the mean diameter at breast height was 260 mm and the average tree height was 18 m. The yield of wood biomass was around 300 tons per hectare.

Pests and diseases

Susceptible to borer beetles, *armillaria*, *phytophthora*, root rot, and sooty mould.

Invasiveness and risks

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

Timber quality

The wood of the Himalayan cedar features light brown heartwood and is quite light. It is very durable, especially when grown in its native range. Essential oils are gathered from the resinous wood and used for various purposes. The timber is characterized by medium bending strength and stiffness as well as low toughness. Due to its unique smell, its hardiness, and the fact that it is easily workable, *Cedrus deodara* wood is often used for buildings and furniture. Further purposes are as ties or in bridges.

Management and prevention if invasive

This species is currently considered non-invasive.

Expert opinion

Cedrus deodara is one of the most frost-hardy cedar species, with young plants in particular exhibiting robustness along with excellent growth. The species needs plenty of light, thrives in poor and nutrient-poor soils, and is tolerant of heat and drought. In the context of climate change, it therefore has great potential for urban and forestry use. There are already several trial areas in European forests. So far, no specific diseases affecting the species are known. Conflicting opinions regarding its wood exist: While it has long been used for various purposes in India, it has no significant economic value in Europe. However, the Himalayan cedar offers considerable ecological value, and its seeds are eaten by birds. Further trials are necessary to fully determine this species' characteristics.

Corylus colurna L.

Turkish hazel

turška leska

Baumhasel

Noisetier de Byzance

Nocciola

Main characteristics:

- Broad-leaved tree species native to the Balkan peninsula and Anatolia.
- Not considered invasive for any ecosystems in Central Europe, the species exhibits perfect characteristics in terms of adaptability to climate change.
- The biggest threat to this tree species are mice, which nibble off the bark, leading to high mortality.

Management and use in Alpine space forests

Although the Turkish hazel can reach up to 30 m in height and has only modest demands, its importance for European silviculture is rather low. The knowledge of foresters regarding the species has increased over the past 20 years, however. It is now often used for erosion protection on sites with dry soils, where cultivation is very complicated. *Corylus colurna* generally develops vertical, well-formed stems that are very attractive from a forestry perspective. Regular thinning from above is essential to maintain a high radial increment. It should not be planted in monocultures and needs to be protected from mice. With regard to the effects of climate change, usage of the Turkish hazel in forestry is expected to become more prevalent in the future, especially to reduce the risk of failure in existing stands.

Pests and diseases

Corylus colurna is resistant to most kinds of pests. Abiotic causes of damage and insects only play a minor role. The biggest threat for the species are mice, which are especially problematic during drought periods when other food sources are rare. Mildew is induced by the species *Phyllactinia corylea*, and the larvae of *Balaninus nucum* can feed on Turkish hazel seeds.

Invasiveness and risks

Due to its very low competitive strength, the Turkish hazel is not expected to be invasive. Numerous long-term plantations across Europe corroborate this assumption: No negative consequences for native flora, fauna, or soil have been noted yet.

Timber quality

The timber of the Turkish hazel is suitable as quality wood with a unique reddish colour. As the tree species grows faster than oak species, quality timber can be produced in shorter periods. Negative aspects include the possibility of ingrown branches and curly grain. Due to the overuse of the natural stands in its native range, only small volumes of timber are available, and no specialized market thus exists for Turkish hazel wood. Besides its employment in cabinetmaking, it is also used for turnery.

Management and prevention if invasive

This species is currently considered non-invasive.

Expert opinion

The Turkish hazel could play a role comparable to that of *Quercus rubra* in Central European forests, and especially in lowlands. The species could be very beneficial for forestry use due to its high resistance to drought, pests, and diseases, its valuable timber, and its lack of invasive potential.

Prunus serotina EHRH.

Black cherry

pozna čremsa

Amerikanische Traubenkirsche

capulin

ciliegio nero

Main characteristics:

- Introduced to Europe from eastern North America in the 17th century.
- Planted in many countries for ornamental purposes, timber, and soil amelioration.
- Invasive and difficult to eradicate due to intensive resprouting.
- Its invasion success can be attributed to its long residence time and high propagule pressure.

Management and use in Alpine space forests

The black cherry has been of interest to foresters since the early 1800s for the production of high-quality timber on poor soils. However, this timber production was not very successful, and the species has therefore been relegated to use in wind- and firebreaks. It was widely planted in the understoreys of European coniferous plantations during the first half of the 20th century to improve litter quality and provide shelter due to its formation of dense patches. Since then, it began to spread spontaneously into forest edges and open forest sites as well as into ecologically valuable areas such as bogs, dry grasslands, and heathlands. In particular, invasions have frequently been recorded on well-drained, nutrient-poor soils, where the black cherry can form a dense shrub and sub-canopy layer.

Pests and diseases

Prunus serotina is known to serve as host for a wide variety of plant pathogens in North America, many of which may be less prevalent or even absent in its introduced European range. The most important pests and diseases are *Armillaria* spp., cherry leaf spot (*Blumeriella jaapii*), pear slugs (*Caliroa cerasi*), shot hole disease (*Stigmina carpophila*), and the *Aromia bungii* longhorn beetle. Potential problems may result from the fact that the species is also a host plant for certain agricultural and forestry pests.

Invasiveness and risks

The black cherry is a widespread invader of European temperate forests, where it tends to form homogeneous stands. It causes substantial management problems in forest ecosystems by suppressing the regeneration of native tree species, and its spread can significantly modify key ecological characteristics (particularly soil properties) and cause biodiversity loss. Despite its disturbance-dependant nature, it is even able to enter forest interiors and form a long-living sapling bank, which is rapidly released upon canopy gap formation with improved light conditions. Plantations in farms can also be considered risky habitats for unintentional spread. *Prunus serotina* possesses many functional traits (e.g., efficient seed dispersal, massive vegetative growth, high degree of ecological adaptability) associated with successful invasive behaviour.

Timber quality

Black cherry wood is light and firm and considered one of the best all-around woods for workability. The heartwood is very durable and resistant to decay. Common uses are cabinetry and fine furniture, flooring, interior millwork, veneer, turned objects, and small specialty wood items. It is especially suitable for dining room suites and large desks and tables. The wood from sprouts can be of high quality and is used for sawtimber.

Management and prevention if invasive

The black cherry possesses an excellent ability to resprout from roots and stumps, which makes it difficult to eradicate. A common silvicultural recommendation is that only large-diameter trees should be felled, while thinner trees should be left untreated. Girdling has proven to be the most effective treatment. All measures need to be repeated over several years. Forest canopy gaps facilitate colonization by this pioneer species, and intensive harvesting approaches (clear-cuts) are thus to be avoided. Other options for controlling the establishment and spread of *Prunus serotina* include underplanting or seeding of shade-tolerant species, maintenance of sufficient overstorey canopy closure, and overall support for natural regeneration of native tree species with a high leaf area index that shade the understorey. *Chondrostereum purpureum* fungus may represent an effective microbial herbicide.

Expert opinion

In several parts of Europe, *Prunus serotina* is one of the most common invasive non-native tree species. There are different approaches to this issue. Many countries fight against the species, removing it because of its invasiveness and trying to limit its spread, which is rarely successful. At the same time, there is little research on or evidence of any greater harmfulness to the natural environment or even human health. In fact, most of the negative attitude towards the black cherry appears to be owed simply 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. Because it produces high-quality wood, its fruits promote biodiversity and the animal inhabitants of forests, and because it has no proven serious negative impact on the environment, it is considered a useful tree species wherever it has spread and integrated into the natural tree composition. However, there is still precious little comprehensive research on the species and its potential in Europe, and it would make sense to accelerate this research. Considering that the black cherry is difficult to remove entirely because it can resprout from stumps, its complete eradication from invaded areas is very costly. This makes alternative approaches seem worth considering.

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, distinctive, heart-shaped leaves.
- Introduced to Europe from China at the beginning of the 19th century as an ornamental plant.
- Valued for its high-quality wood used in furniture, decorative products, and musical instruments.
- Potentially invasive in Europe.

Management and use in Alpine space forests

In Europe, the princess tree is mainly used in plantations for timber and bioenergy generation. It likely cannot play an important role as a forest tree in the Alpine space, as it is shade-intolerant and thus unable to establish in forest systems where the canopy is too dense for it to regenerate. It can, however, occur quite invasively in disturbed vegetation and must therefore be observed carefully in the future.

Pests and diseases

Little is known about the vulnerability of *Paulownia tomentosa* to diseases and pests in Europe. In the USA, damage from several foliage diseases (*Phyllosticta paulowniae*, *Phyllactinia guttata*, and *Uncinula clintonii*) and polyphagous pests (*Mylabris pustulata* and *Helicoverpa armigera*) has been reported. *Eumeta variegata* is a defoliator and the most important pest found on the princess tree in its nature range; it spreads with seedling stock. Paulownia witches' broom (PWB) disease is caused by a phytoplasma and often found in plantations. It is spread by the stink bug *Halyomorpha picus* and causes distinctive yellow broom-like shoots that die back in the autumn. Anthracnose disease is a major disease in saplings that injures leaves, petioles, and shoots a well as causing leaf drop. Among the fungus-induced diseases are damping off caused by *Rhizoctinia solani* and *Fusarium* spp. *Sphaceloma tsugii* damages seedling shoots and causes dieback. The nematode *Meloidogyne marioni* infects seedling roots, leading to mortality.

Invasiveness and risks

As a pioneer species, the princess tree predominantly establishes on open sites. In Europe and elsewhere, it has established in forest clearings and disturbed open habitats. A key limiting factor for the species' invasive success are low winter temperatures. It can spread vegetatively as well as by seeding. The seeds are dispersed by water and wind up to 3.5 km from the mature plant and remain viable for a long time. Its invasiveness should be monitored in the future, however, as the species could potentially also colonize more natural habitats, especially considering the predicted changes in climatic conditions. Outside of Europe, the princess tree is classified as invasive in North America and New Zealand.

Timber quality

The princess tree is valued greatly for its high-quality wood. Plantations are therefore cultivated for noble timber production in Asia, the USA, and Europe. The wood is very light, with a straight grain and low shrinkage. It is easy to plane, saw, and carve, and is flame resistant with a very high flash point of 420 °C (about 50% higher than other forest wood). It is used for furniture, model airplanes and gliders, and for interior panels on airplanes, ships, and vehicles. It is also valued for the manufacture of musical instruments and beehives. An instrument maker in Konstanz (Germany), for example, built guitars of princess tree wood for the well-known musician Prince. In China, *Paulownia tomentosa* wood is widely used for various practical and ornamental objects.

Management and prevention if invasive

Once the species has established, it is recommended to eradicate it by pulling out seedlings, removing the entire root by hand before the taproot is well developed. Felling adult trees close to the ground and repeatedly spraying the remaining stump with herbicides is also effective. Complete elimination is necessary since the princess tree is highly capable of vegetative regeneration via root brood and stick rash. If required, seed production can be avoided by girdling. To prevent any ecological risks, the species should not be cultivated on a larger scale or near open habitats of high conservation value.

Expert opinion

More than 30 years ago, the princess tree was cultivated in plantations in Germany and processed into wood chips, but the species did not prove sufficiently resistant to frost. Further cultivation attempts were undertaken to produce valuable wood, which became very popular and is still widely traded. Various European projects to cultivate the princess tree in plantations for valuable timber exist, but they generally require intensive nursery care and extensive irrigation. Examples of companies operating such plantations with the aim of selling wood and whole trees as a value investment are WeGrow and treeme, with plantations in Germany and Spain. The princess tree grows better in the Mediterranean area. The potential invasiveness of the hybrids grown in plantations (mostly "Shang-Tong") is likely reduced by the cutting of all inflorescences.

Paulownia tomentosa is recommended to be grown exclusively on well-selected sites and with the right choice of seed. Only then can it be a good alternative to native tree species. Suitable locations should feature loose, deep soil that both drains and warms up quickly. The minimum temperature for the princess tree is -15 °C, and it does not tolerate early or late frosts, which lead to leaf loss. The most favourable cultivation conditions of *Paulownia* are found up to about 180 metres above sea level, such as in as in the Po Valley (Italy) and Rhine Valley (Germany).

In their first years, princess trees need sufficient rainfall – more precisely, around 700 mm a year, and especially during summer. In terms of pests and diseases, only browsing damage by mammals poses a problem. No fungal infections or diseases caused by bacteria or viruses have been observed in optimal locations.

Picea omorika (PANČIĆ) PURK.

Serbian spruce

omorika, Pančićeva smreka

Serbische Fichte

Epicea de Serbie

Abete rosso della Serbia

Main characteristics:

- Endemic relic of the European flora of the pine family.
- Narrow-crowned and slender coniferous tree species.
- Current natural distribution limited to a small area in the central Balkans between Serbia and Bosnia and Herzegovina.
- Threatened and endangered.

Management and use in Alpine space forests

Picea omorika is native to the mountainous border area between Serbia and Bosnia and Herzegovina in the central Balkan region. Besides a few experimental plots, it is not used for silvicultural purposes to any significant extent outside its natural range. In Bosnia and Herzegovina, it is successfully employed in the reforestation of high-altitude areas. In the Alpine space, it is regularly used only for urban greening due to its air pollution tolerance.

Pests and diseases

Many fungi can infect the Serbian spruce and especially its roots, such as Armillaria mellea (often fatal) and *Rhizina undulata*. On calcareous soils, *Heterobasidion annosum* can cause red rot, but this is usually not a serious problem. Within and outside its natural range, the species is also attacked by various species of bark beetle (e.g., *Ips typographus*, *Xyloterus lineatus*, *Pityogenes chalcographus*, and *Dendroctonus micans*). The large pine weevil (*Hylobius abietis*) is one of the most dangerous pests in young coniferous forests in Europe. *Liosomaphis abietina* and *Pissodes strobi* appear occasionally as pests as well. In newly populated areas, the species often exhibits a browning of the needles at the shoot tips. This phenomenon, known as omorika dieback, is caused by the accumulation of chlorine ions in the root system as a result of large amounts of building rubble in the soil. Some sources mention that aphids, mites, scale insects, and budworms are likewise problematic for the species.

Invasiveness and risks

This species is currently considered non-invasive.

Timber quality

The wood of the Serbian spruce is similar to that of the Norway spruce. The quality timber was once highly valued as a building and construction material due to its technical properties. There are hardly any differences in colour between heartwood and sapwood. The late wood is slightly darker – yellow or brownish – than the early wood, and the wood fibres contain numerous resin channels. In ancient and medieval times, *Picea omorika* was used for the production of ship masts and beams as well as for the manufacture of special cheese pots. Today, it is primarily valued for its aesthetic qualities, e.g., as decorative brushwood or Christmas trees.

Management and prevention if invasive

Non-invasive species.

Expert opinion

The Serbian spruce is not invasive and does not affect other species. It is threatened by anthropogenic and natural influences, and its extremely poor regenerative capacity in conjunction with climate-related changes endangers the survival of the species. The summer droughts of recent decades in its natural habitat have caused negative growth rates. Reforestation with *Picea omorika* should therefore be promoted outside its native range at locations suitable for its future growth. Ex situ objects (e.g., plantations, progeny experiments, etc.) should be established to preserve the genetic diversity of the species. Active management of the populations of *Picea omorika* is currently prohibited. However, recent studies have recommended management practices aimed at reducing the effects of drought, for example by reducing competition for water resources and promoting natural regeneration.

Picea pungens ENGELM.

Colorado spruce, blue spruce

srebrna smreka

Blaufichte, Stechfichte

Épicéa du Colorado

abete del Colorado, picea pungentee

Main characteristics:

- Subalpine species native to the Rocky Mountains in North America.
- Coniferous tree with blue-green needles.
- Planted as an ornamental tree in urban areas, also used as for Christmas trees.

Management and use in Alpine space forests

Currently used sporadically in European forests, far from its natural habitat in Colorado and Utah. It is considered an ornamental tree.

Pests and diseases

In North America, the blue spruce is attacked by two species of *Adelges*, an aphid-like insect that causes galls to form. Mites can also infest the species, especially during dry summers, causing yellowing of the oldest needles (Gilma et al., 2011). The spruce beetle (*Dendroctonus rufipennis*) bores under the bark of *Picea pungens* in North America but is not yet present in Europe. It primarily attacks fallen trees, and when the larvae mature two years later, a major outbreak occurs, with vast numbers of beetles attacking nearby standing trees. The species is also susceptible to several needle casting diseases, which cause the needles to turn yellow, mottled, or brown and fall off. Various rust diseases likewise affect the Colorado spruce, resulting in yellowing and loss of needles.

Invasiveness and risks

Presumably does not pose a serious invasiveness risk, as it is not known to be a pioneer species.

Timber quality

Picea pungens is not an important timber tree in its native range, since it occurs only sporadically and the wood is brittle, weak, and light, with many knots and resin canals. The blue spruce and its many cultivars are often grown as ornamental trees in gardens and parks, however. It is also grown for the Christmas tree industry.

Management and prevention if invasive

This species is currently considered non-invasive.

Expert opinion

Due to its high tolerance for acid rain, the blue spruce has been among the non-native tree species most frequently used for reforestation in spruce mountain forests in Central Europe. Many trees were affected by a massive outbreak of the fungus *Gemmamyces piceae*, however, and numerous plantations infected by the pathogen had to be cut down. Although several resistant genotypes have been found, the species has decreased in popularity among foresters and Christmas tree plantation managers, not least because many other pathogens and pests affect its performance as well.

Picea sitchensis (BONG.) CARR.

Sitka spruce

sitka

Sitka-Fichte

Épinette de Sitka

Il peccio di Sitka

Main characteristics:

- Native to North America, where it grows naturally in coastal areas.
- Introduced to Europe in the 18th century.
- High precipitation and heat demand supported only by the oceanic climate along the north-western coasts of Europe.

Management and use in Alpine space forests

The Sitka spruce will not be an option for forestry in the Alpine region, as its ecological amplitude is quite small and its need for oceanic climate (mild winters and high precipitation) is not met. Considering climate change and its impact on the precipitation regime, the use of Sitka spruce in the Alpine space in the future seems even less likely. In Europe in general, however, it is currently the non-native tree species with the second highest importance for forestry, with plantations in Ireland and the UK as well as rare occurrences in the Netherlands, among others. Silvicultural management should promote mixed stands to reduce the potential risks. The Sitka spruce has a high demand for light, and the crown space should therefore be adapted early on. However, it is also possible to regenerate stands naturally or artificially under a canopy. The first thinning phase should take place at a height of 12 to 15 metres, depending on the crown length of the trees.

Pests and diseases

The threats affecting the Sitka spruce in its native range are different from the pests and diseases existing in Europe. Compared to native conifers, *Picea sitchensis* shows a higher resistance to pathogens on places with ideal locational and climatic properties. Outside such areas with suitable site conditions, however, the species is very unlikely to withstand biotic and abiotic threats. In its natural distribution area, the biggest abiotic threat to the Sitka spruce is damage by windthrow. The weevil species *Pissodes strobi* and *Steremnius carinatus* cause serious

damage in North America as well, with high mortality rates in younger stands. *Dendroctonus rufipennis*, the spruce beetle, is responsible for periodic diebacks of huge stands in North America since the 1990s and could contribute to the dieback of weakened Sitka spruce stands if introduced to Europe. Root and stem injuries make the trees more susceptible to infections by fungi like *Armillaria ostoyae* and *Heterobasidion annosum*. Other pathogenic fungi including *Rhizinia undulata*, *Phaeolus schweinitzii*, *Phellinus weirii*, and *Cylindrocarpon destructans* contribute to the susceptibility of Sitka spruce stands to windthrow, as they induce root rot. The Douglas fir woolly aphid (*Gilletteella cooleyi*) causes galls on the shoots and cankers on the branches. *Liosomaphis abietinum* leads to decreases in growth or, in severe cases, to the death of entire stands. *Phytophthora ramorum* is an impending threat to the Sitka spruce as well, having occurred on conifer tree species for the first time in 2009.

Invasiveness and risks

Picea sitchensis is not considered invasive in most European countries and generally presents no danger for natural ecosystems. Its invasiveness is limited to a very small area along the coastal heathlands of Norway with specific climatic conditions. There, however, it has changed the microclimatic conditions and forest floor species composition, threatening a landscape of high conservation value. Since 2012, the species has been blacklisted in Norway as a precaution. In Ireland, where the Sitka spruce has been used for silvicultural purposes for a long time and dominates 60 percent of all plantations, it is not considered invasive.

Timber quality

The wood of the Sitka spruce is coloured from white to yellow, with no apparent border between heartwood and sapwood. It has a fine texture and regular, straight grain. The timber is highly appreciated by the paper industry. Its combination of good mechanical properties and low weight also makes it suitable for use as construction wood. It is also employed in furniture and boatbuilding, wind turbine blades, and musical instruments. In general, *Picea sitchensis* timber is cheap and easily accessible on the market.

Management and prevention if invasive

Creation of buffer areas: new Sitka spruce plantations are recommended to be created no closer than 200 metres to protected areas. This applies especially to forest enterprises located in coastal areas. An important measure for reducing the susceptibility of coastal heathlands to Sitka spruce invasion is the prevention of fires, since the charcoal created during such events absorbs phytotoxins produced by the heath species and prepares the soil for the regeneration of *Picea sitchensis*. On most sites where the Sitka spruce occurs, it shows only minimal invasiveness, thus making no special measures necessary. Removal strategies can be applied during state-of-the-art tending measures for natural regeneration or during first thinning.

Expert opinion

The Sitka spruce is a key species in Ireland, dominating 60% of the country's plantations. It is a very versatile species and will grow on a wide variety of soils under a different climatic condition. Numerous different provenances from western North America are available to fit most conditions, and the species can exhibit strong natural regeneration in areas where the soil and climatic conditions are favourable.

The limited invasiveness of *Picea sitchensis* is not considered a problem in the Netherlands. The Dutch experience is that while the Sitka spruce grows very fast, sometimes outgrowing the Norway spruce, it is not a very attractive tree otherwise. It is not being planted anymore but may be maintained in the regeneration if it occurs; in general, however, other species such as Douglas fir, beech, or even Scot's pine are preferred. Silvicultural management is largely the same as for Norway spruce stands, but since even-aged monoculture production forests are becoming rare in the Netherlands, this is no longer very relevant. There is actually very little Sitka spruce left in the Netherlands, only in incidental small stands or admixtures. In the 2014 National Forest Inventory, the species was recorded as being present on only 7 of over 3,000 plots.

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.
- Five 3-sided needles and cylindrical grey-brown seed cones 8–20 cm long.
- One of the economically most important species and of great interest for forestry; also planted as an ornamental tree in parks and gardens.
- Widely planted in Europe, then abandoned due to blister rust during the 20th century.

Management and use in Alpine space forests

The eastern white pine's growth potential and other silvicultural features justified its early introduction and temporary spread across several European countries. Blister rust was and continues to be the major limiting factor for the introduction and spread of the species, however. Natural regeneration has been observed up to two generations when blister rust is absent, as in some areas of Switzerland and Germany, and when *Pinus strobus* is mixed with *Fagus sylvatica*, *Pinus sylvestris*, and some common spruces.

Pests and diseases

There are a total of 277 insects and 110 disease organisms known to attack the Weymouth pine, though only 16 insects and 7 diseases cause sufficient injury or mortality to be of concern. The three most important are the white pine weevil (*Pissodes strobi*), white pine blister rust (*Cronartium ribicola*), and *Armillaria mellea*. Blister rust is highly virulent throughout the entire range of white pine, and trees are susceptible from the seedling stage through maturity. The disease can cause high losses both in regeneration and in immature timber stands. It can be controlled by selection and genetic improvement. However, the typical silvicultural protective methods should be applied as well: clear-cutting currant bushes (the source of infection) in the proximity of new plantations, avoidance of pure eastern white pine stands on large areas, and simultaneous introduction of mid- and understorey shrubs, whose crowns have the capacity to limit the migration of blister rust spores.

Invasiveness and risks

Pinus strobus is considered an invasive species in the Czech Republic, Germany, and Hungary among other countries. It has been planted at a large scale, but invasions are rarely reported. In the Czech Republic, the species is presently highly invasive in several primarily sandstone areas, but non-invasive in most other locations. 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 because of their unique environment, and large-scale regeneration of any alien tree species in these areas is therefore a serious conservation concern. Pinus strobus seeds can disperse up to 750 m from the source.

Timber quality

Traditionally, the trunk of the tree was used for ship masts. The valuable wood is fine-grained and contains little resin, making it very suitable for construction and furniture. Weymouth pine wood has medium strength, is easily workable, and stains and finishes well. It is used for doors, mouldings, trim, siding, panelling, furniture, patterns, matches, and many other items.

Management and prevention if invasive

There is no evidence of large-scale management efforts in Europe. However, close monitoring should be performed to identify invasive populations and control them at an early stage.

Expert opinion

The eastern white pine is often classified as an invasive tree species and should therefore be used only in forests that are very unnatural. It offers much better growth performance than the Scots pine and produces versatile timber that can be used for windows, door frames, ship and boat construction, pulp, and cellulose.

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 mountainous regions of Afghanistan, Pakistan, India, Nepal, Bhutan, Tibet, China, and Burma.
- Spans an altitudinal range between 1,500 and 3,800 m in its natural range.
- 12- to 18-cm-long blue-grey needles in fascicles of five.
- Fast-growing tree important for timber production.

Management and use in Alpine space forests

Currently used only sporadically in European forests far from its natural habitat in the mountainous regions of Asia, as it is mainly considered an ornamental tree.

Pests and diseases

Needle blight disease is an issue in the Himalayan white pine's native range. Temperature, relative humidity, wind speed, and rainfall influence the disease's expression, with favourable temperature and wind speed constituting particularly important parameters for the development of needle blight. Also susceptible to honey fungus (*Armillaria mellea*), which attacks the roots and leads to their decay, causing trees to die.

Invasiveness and risks

No invasiveness has been documented, and the potential seems low as the species grows in cool, deep soil and does not tolerate drought and heat. It prefers a humid climate and sheltered locations and is easy to control it as it does not sprout.

Timber quality

The Bhutan pine is an important timber tree in many parts of the Himalaya. Its wood is similar in quality and properties to that of *Pinus strobus* in North America. Tall, straight trees produce straight-grained timber of good strength. The wood is moderately hard, durable, and highly resinous. It is used for construction, carpentry and joinery, wall panelling, veneers, furniture, fences and gates, crates and boxes, and railway sleepers. In India, its resin is used for naval stores, and honeydew secreted by aphids is collected by locals for consumption. *Pinus wallichiana* wood can also be used as firewood despite giving off a pungent resinous smoke and is a commercial source of turpentine.

Management and prevention if invasive

This species is currently considered non-invasive.

Expert opinion

It is difficult to assess what benefits this species could bring compared to the native Alpine pine species, which are probably more drought resistant.

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).
- Timber used in the wood industry (plywood, light packaging) and for sawing.

Management and use in Alpine space forests

Populus × *canadensis* is not a forest tree. It is primarily cultivated to produce wood on plantations frequently located in open fields or valleys. It can occasionally be encountered in the mountains under certain soil conditions (depth, humidity) and at low altitudes. The species is rarely found in the Alpine region, mostly when planted by humans in valleys or along rivers. Robust cultivars resistant to pathogens and capable of adapting to different climatic situations have been obtained by genetic manipulation. The Canadian poplar is cultivated all across the temperate zone – more frequently in eastern and north-eastern regions and to a lesser extent in southern regions.

Pests and diseases

The Canadian poplar's sensitivity to pests and pathogens varies depending on the cultivar employed: It can be affected by aphids (woolly aphids: *Phloeomyzus passerinii*) as well as by fungal and bacterial diseases (*Melampsora*, *Marssoninae brunnea*, *Xanthomonas populi*). In case of stress, the parasite Dothichiza (*Discoporium populeum*) can also appear. Poplars located on suitable sites and managed according to forestry recommendations will be less vulnerable to pests and diseases.

Invasiveness and risks

Not considered an invasive species. Nevertheless, it can rarely cross spontaneously with *Populus nigra*. In this case, there is a risk of introgression due to the genetic proximity to *Populus nigra*, the original species.

Timber quality

Canadian poplar timber is used by the wood industry (plywood, light packaging) and for sawing. Under certain humidity-free conditions, the wood can be very resistant and can be used in construction (lumber). Otherwise, it is employed to produce wood panels or paper. Thanks to its rapid growth, the species supplies a large amount of timber on comparatively small areas (around 210 000 ha) in France, where it is the second most productive deciduous species harvested for timber, after oak and before beech.

Management and prevention if invasive

This species is currently considered non-invasive.

Expert opinion

Populus × *canadensis* is a plant cultivated for green biomass. It needs deep and cool or wet soil, is not adapted to mountainous areas, and quickly suffers from drought stress. It is a relatively common species in French fields and valleys, where it is mostly grown for wood. Could be interesting for phytoremediation.