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526 non-native tree species growing in the Alpine Space

Inventory of non native tree species in the Alpine Space

ALPTREES REPORT

90% have their natural distribution range outside of the European geographical area

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352 non-native tree species cultivated in urban areas

Aesculus hippocastanum and Robinia pseudoacacia are the most common non-native tree species in cities

Most of them come from Asia and North America

161 non-native tree species are growing in both urban areas and forests/forest plantations

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Report on Database with inventory on NNT in the Alpine Space

Inventory of NNT in the Alpine Space

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Summary

This study in Working Package WPT-1 aimed to perform an inventory of non-native tree species growing in Alpine Space forests and cities, analyzing their diversity, distribution, and geographic origin.

Our results show that at least 526 NNT are currently growing in forests and urban areas in the Alpine Space. The number of NNT growing in urban areas (352) is much higher compared to woodlands (13), yet a considerable large number were reported for both urban areas and forests (161). These figures clearly show that a large proportion (67%) of reported NNT are currently being cultivated exclusively in cities in the Alpine Space. Of these, the most common NNT are *Aesculus hippocastanum* (horse chestnut), *Robinia pseudoacacia* (black locust), and *Gleditsia triacanthos* (honey locust).

Most of the reported NNT (90%) have their natural distribution range outside of the European geographical area. The largest number of these species were introduced from Asia (248) followed by North America (180).

About 5% of reported NNT have been considered (potentially) invasive in one or several regions of the Alpine Space. Most of them have their native distribution range in North America.

NNT are widely used in the Alpine region for landscaping and horticultural purposes (35%). Other frequently mentioned benefits include their use as an ornamental tree or their potential to sequester carbon.

1. Introduction

1.1 Cultivating non-native tree species in a changing climate

Anthropogenic climate and land use change pose major threats to the ecosystems in the Alpine Space. Native tree species are increasingly affected by pests, diseases, drought, and higher temperatures (Allen et al. 2010). Commercially important native forest tree species such as Norway Spruce (*Picea abies* (L.) H. Karst.) or European Beech (*Fagus sylvatica* L.) have turned out to be susceptible to increasing summer drought (De Avila and Albrecht 2018). Urban trees are also affected by the changing climate as most likely urbanized areas will be hotspots of the projected temperature increase (Roman et al. 2014). In consequence, some tree species might become unsuitable and increased climatic extremes could lead to an increased susceptibility of urban trees to certain pests and diseases (Tubby and Webber 2010). Climate change could bring many of our (urban) forests to a tipping point where they can no longer provide the ecosystem services that we demand of them. Therefore, integrated management efforts are required to respond to the potential negative effects, connecting mitigation and adaption efforts as well as economic and biodiversity goals. Against this background, the use of potentially climatically better adapted non-native tree species (NNT) in forests and urban areas are being increasingly discussed (Bolte et al. 2009; Keča et al. 2019; Sjöman et al. 2016). Yet, simultaneously, large-scale cultivation of certain NNT can entail risks for biodiversity and ecosystem functions (Castro-Díez et al. 2019) and thus using potentially invasive NNT can conflict with conservation or socio-economic objectives in the Alpine Space.

1.2 Definitions

NNT in the Alpine Space region include tree species, breeds or hybrids, whose presence there is a result of human activity, due to intentional or accidental introduction (see Table 1 for definitions). Depending on the time of introduction, they can be separated into Archaeophytes and Neophytes. NNT, which have been considered invasive or potentially invasive in one or several regions of the Alpine Space are hereinafter referred to as "(potentially) invasive non-native tree species".

Table 1 Terms used to classify and define occurring tree species in the Alpine Space (the scheme is adapted from BfN: *https://neobiota.bfn.de/grundlagen/neobiota-und-invasive-arten.html*)

<table>
<tr><td rowspan="4">Native trees refer to tree species of natural, post-glacial forest development in the Alpine Space region.</td><td colspan="3">Non-native trees (NNT) also known as "non-indigenous", "alien", "introduced", "allochthonous" or "exotic" trees, refer to tree species, breeds or hybrids in the Alpine Space region, whose presence there is as a result of human activity, due to intentional or accidental introduction.</td></tr>
<tr><td rowspan="3">Archaeophytes include NNT introduced to the Alpine Space intentionally or unintentionally that became naturalized there prior to the year 1492.</td><td colspan="2">Neophytes include NNT introduced to the Alpine Space intentionally or unintentionally that became naturalized there after 1492, when Christopher Columbus arrived in the New World and the Columbian Exchange began.</td></tr>
<tr><td>Non-invasive trees refer to NNT that do not show or suggest any negative impact so far, or their effects are unknown.</td><td>(Potentially) Invasive trees refer to NNT whose introduction, establishment and/or spread pose potential or actual risks to the native biodiversity, ecosystem functioning, or socio-economy including human health.</td></tr>
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1.3 Inventory of NNT

It is important to address the patterns and potential positive and negative impacts of NNT dispersal in the Alpine Space in order to provide a useful set of guidelines for managers, as for example, forest management has a regulatory effect on the distribution of NNT (e.g. Martin and Marks 2006). Developing a comprehensive database on present NNT in the Alpine Space (Figure 1) is therefore key for assessing their potential risks and benefits in forests and urban areas. More specifically, relevant data is crucial for the production of risk maps and the formulation of spatially explicit projections of distribution and provision of ecosystem services by NNT under different management

and climate change scenarios. There is already extensive research on NNT growing in forests and forest plantations at European level (Brus et al. 2019). However, there are no data yet on the occurrence of NNT across the Alpine Space, and particularly on NNT growing in cities. Within the Alpine Space, the only study addressing NNT in urban landscapes was conducted by Schlaepfer et al. (2020) in Geneva. This research found that 90% of forest tree species and 40% of non-forest trees in Geneva are non-native.

Figure 1 ALPTREES Regions in the Alpine Space.

To fill this knowledge gap for the Alpine Space, we have created a comprehensive database on the occurrence of NNT in urban areas as well as forests or forest plantations. For data collection, we have only considered the administrative units that officially belong to the Alpine Space (Figure 1). With regard to the time of introduction of the NNT to the Alpine Space, we have separated species into Archaeophytes and Neophytes (see Table 1 for definitions). In terms of origin, we have further grouped NNT into species that are native to parts of Europe ("native to Europe") and species that are non-native to the entire geographical area of Europe ("non-native to Europe"). Where available, we included additional information on ecosystem services provided by NNT as well as information regarding their invasive potential. Moreover, we included native trees in the database for two reasons: first, the status "native" or "non-native" to the Alpine Space is not always obvious at first glance for each tree species and thus needs careful literature review. Second, we wanted to be able to relate the native and non-native species in both forests and cities.

2. Results

2.1 Included data sets and references

In total 85 data sets and references were included in the data collection of which more than the half cover tree species in urban areas (Figure 2, see Table S3 in the Supplementary Material 1 for details). Most important for the data collection in the urban environment are tree cadastres, which provide comprehensive information about the existing trees in cities. Overall, we have received 46 tree cadastre data sets of cities located in the Alpine Space (see Figure 3 for distribution of cities, see Table S4 for details). Information on NNT occurrence in forests or forest plantations were primarily derived from NFI databases or other regional forest inventories. In addition, we included information from websites, such as the internet platform "iNaturalist" (*https://www.inaturalist.org/*), books, and reports.

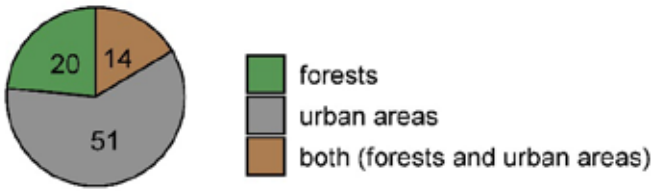

Figure 2 Data sets and references included in the comprehensive database on NNT occurrences in the Alpine Space.

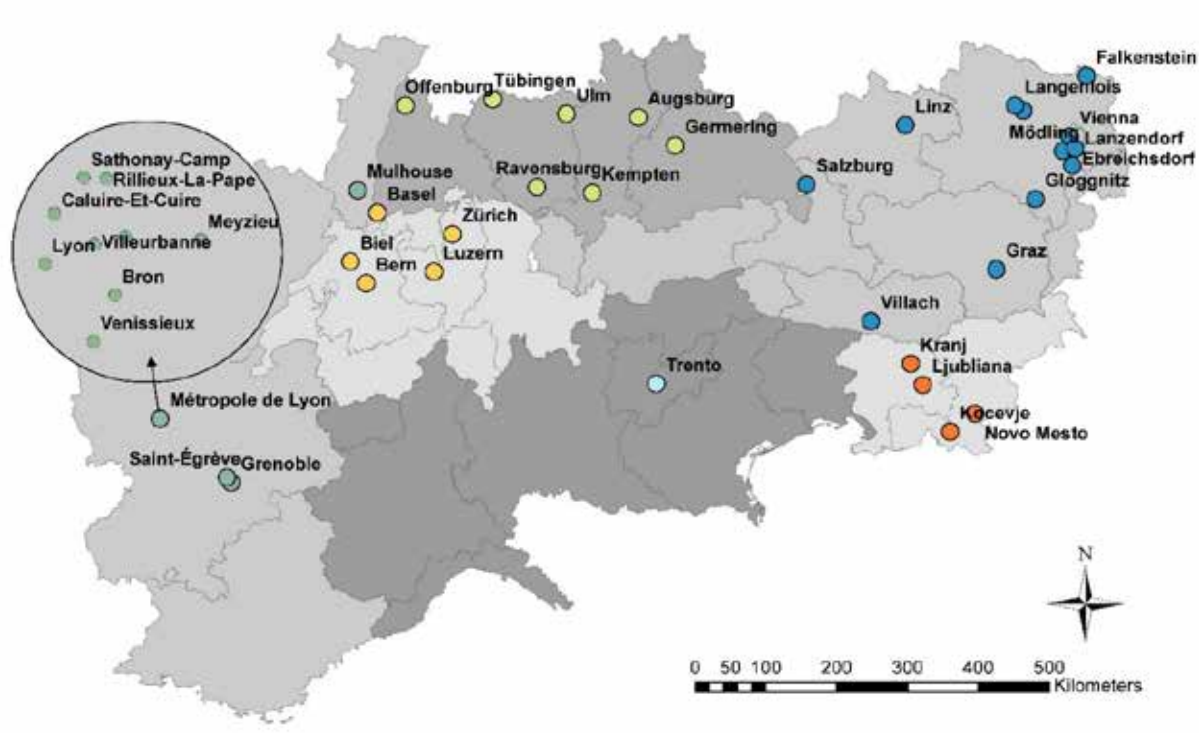

Figure 3 Distribution of cities that provided tree cadastre data sets with individual trees and coordinates across the Alpine Space.

2.2 Proportion, time of introduction and native range of non-native tree species across the Alpine Space

Within the Alpine Space, 648 tree species were reported as being planted or grown in cities and forests or forest plantations. Of these, 526 tree species could be identified as non-native (81%) (Figure 4a). Among the total 81 hybrids included, 12 could not be classified as either native or non-native to the Alpine Space. Overall, Switzerland and

Austria had the highest proportion of NNT whilst Slovenia had the lowest (Figure 4b). See Supplementary Material 2 for the entire list of all reported NNT and additional information regarding their native range, time of introduction, invasive potential, area of occurrence, and benefits.

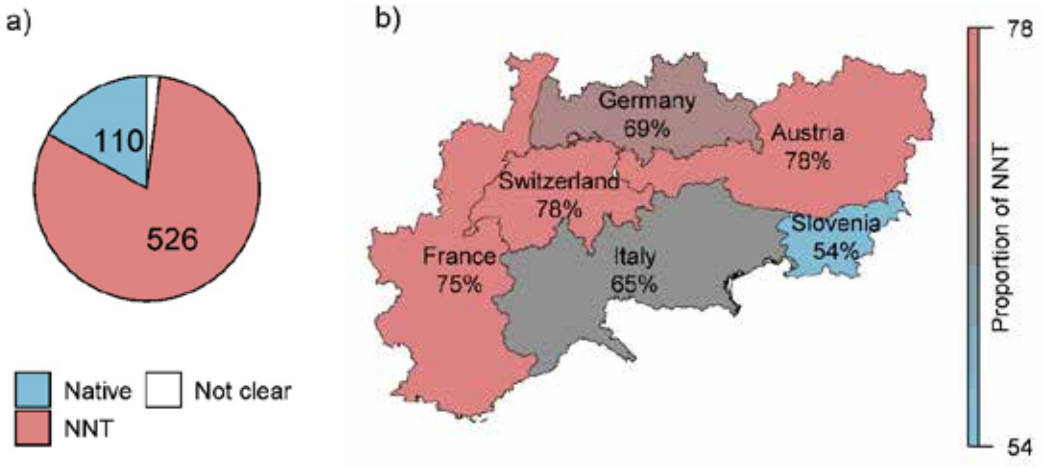

Figure 4 NNT occurring in urban areas and forests or forest plantations in the Alpine Space: a) Numbers of native and non-native tree species; Hybrid species that could not be classified, were labeled „Not clear" b) proportions of NNT per country.

Of the 526 NNT, 5% are Archaeophytes (Figure 5a, see Table S1 in the Supplementary Material 1 for details), 11% have their natural distribution range in parts of Europe outside the Alpine Space region (Figure 5b) and 5% have been considered (potentially) invasive in one or several Alpine Space regions (Figure 5c, see Table S2 for details).

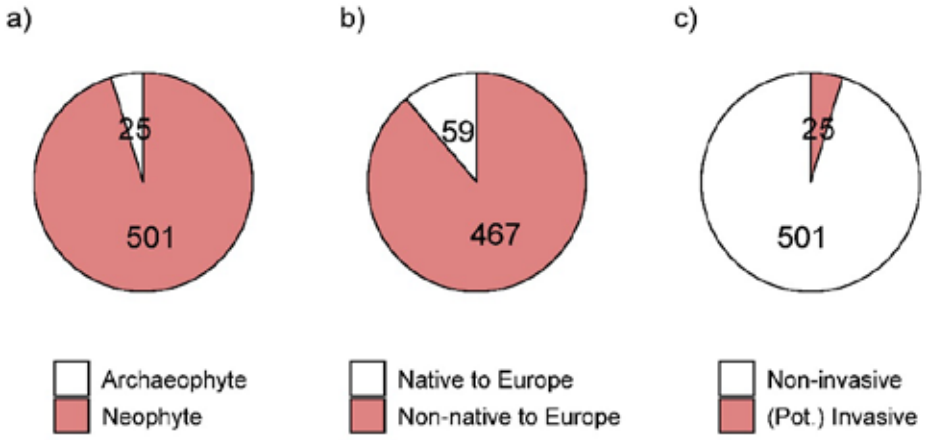

Figure 5 Number of NNT in the Alpine Space separated by: a) time of introduction, b) native range: Native to Europe = non-native to the Alpine Space but native to parts of Europe, c) Invasiveness: (Pot.) Invasive = considered (potentially) invasive in one or several regions; Non-invasive = species not yet considered invasive.

2.3 Non-native tree species in urban areas and forests or forest plantations

At the level of the entire Alpine Space, 352 NNT (67%) were reported as being planted or grown in urban areas while only 13 NNT were exclusively assigned to forests or forest plantations. This low number, however, is due to the fact that species in urban areas also include those in parks, cemeteries or even urban forests, where typical forest tree species are often found. Thus, 161 NNT (31%) were reported for both urban areas and forests (Figure 6a). Overall, the diversity of NNT used in urban areas is much higher compared to forests or forest plantations at the entire Alpine Space as well as in each individual country. The number and proportions of NNT in forests

and urban areas vary across the individual countries in the Alpine Space (Figure 6b). The largest numbers and proportions of NNT in urban areas can be found in Switzerland, Austria and France (Figure 6b).

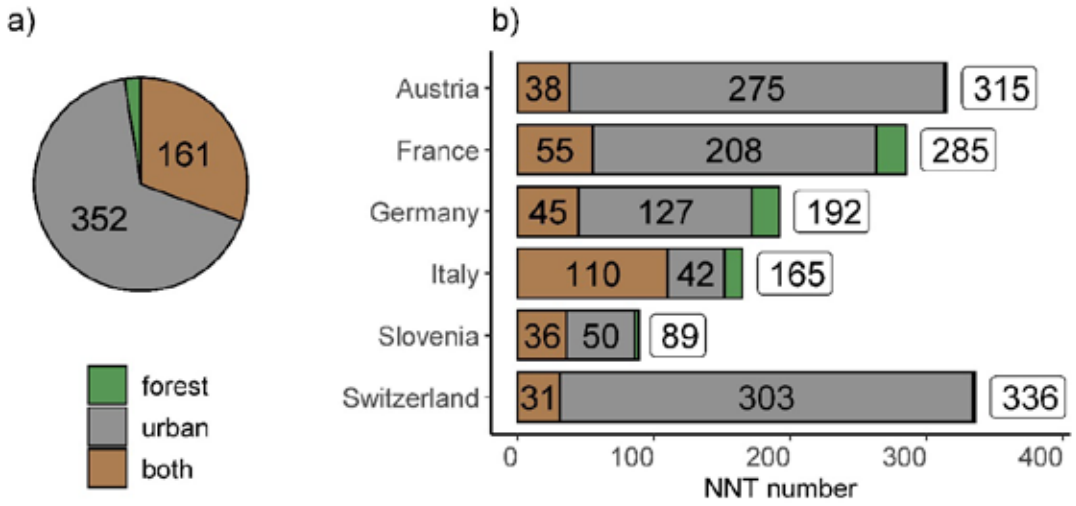

Figure 6 NNT growing in forests, cities or both forests and cities a) across the entire Alpine Space region, b) for the individual countries in the Alpine Space. The box contains the total number of NNT in each case.

2.4 Geographic origin of non-native tree species in the Alpine Space

The largest number of NNT, which are non-native to Europe, were introduced to the Alpine Space from Asia (248, i.e. 53%), and North America (180, i.e. 39%) (Figure 7a). The largest number of NNT, which are native to parts of Europe, were introduced from southern or south-east Europe, such as from the Balkans (10, i.e. 17%), southern Italy (10, i.e. 17%), or from the entire Mediterranean region (9, i.e. 15%) (Figure 7b). Over the half of NNT that are classified as (potentially) invasive have their native distribution range in North America (Figure 7c).

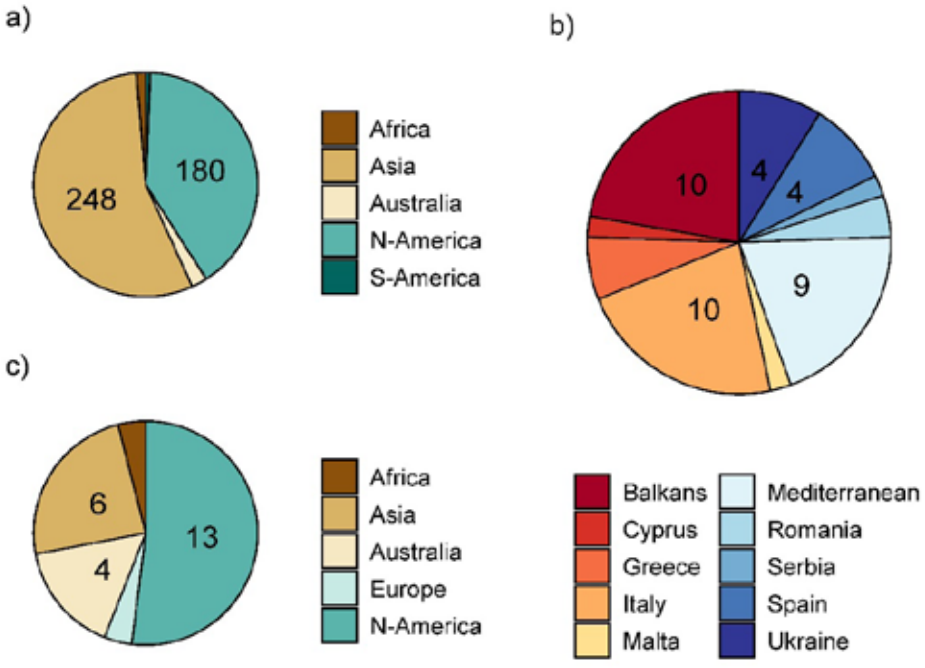

Figure 7 Origin of non-native tree species: a) non-native to the entire European geographical area, b) non-native to the Alpine Space but native to parts of Europe c) (potentially) invasive in the Alpine Space.

2.5 Uses and ecosystem services provided by non-native tree species

Although the data on benefits of NNT were not consistently recorded for all tree species, we were able to compile information on key ecosystem services for the majority of all species. Based on this data, 35% of the NNT are being cultivated for landscape and gardening purposes (Figure 8). 18% are used as ornamental tree, for example, in parks or arboreta, and 15% are being valued for their potential to sequester carbon. Other commonly mentioned benefits include fuel wood, shading, soil erosion control and timber production.

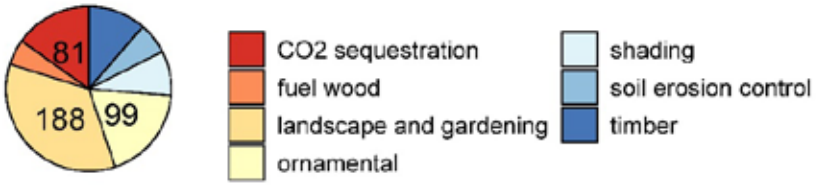

Figure 8 The most frequent uses and ecosystem services provided by non-native tree species in the Alpine Space.

2.6 Non-native tree species in urban areas

A large part of the collected data for urban areas comes from tree cadasters, which typically contain a digital list of all city-owned trees. A tree cadastre serves as a directory in which trees are managed and all recorded trees must be clearly identified. Depending on the city or municipality, different types of data are being collected for the individual trees. In addition to the species name, certain parameters were included for each assessed tree, for example, trunk or crown diameter, tree height, number of stems, coordinates of each tree, etc. Such data allows for more detailed analysis on NNT frequencies, trunk dimensions and abundances in urban areas. Within the framework of this deliverable, we have mainly focused on the frequency of certain species. For example, the ten most common NNT are listed in Figure 9a. The three most frequently planted NNT in urban areas are *Aesculus hippocastanum* (L.), *Robinia pseudoacacia* (L.), and *Gleditsia triacanthos* (L.). 9b shows how the shares of the individual tree species are distributed among the countries. While some species such as *A. hippocastanum*, are planted fairly evenly across countries, *Acer saccharinum* is primarily found in Switzerland, and *Malus domestica* (Borkh.) and *Tilia x euchlora* (K.Koch) in France.

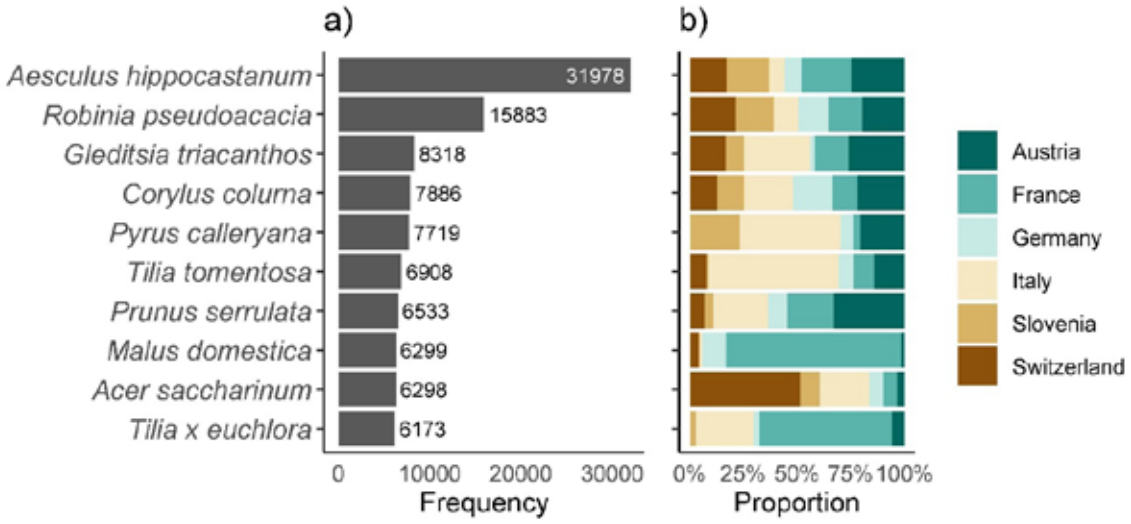

Figure 9 The ten most frequent non-native tree species in cities of the Alpine Space. a) The frequency reflects the number of planted trees b) Distribution across the countries normalized by the total number of trees surveyed in the respective country.

3. Data limitations

Differences in the numbers and proportions of NNT between countries may be influenced by the quality and number of studies being available. For example, the number of tree inventories of cities varies greatly between countries (e.g. 1 city in the Italian region vs. 12 cities in Austria). Based on our experience with data analysis, it has been shown that the number of NNT increased with the number of tree cadastres included. Therefore, we assume that tree diversity in some urban regions is actually even greater than previously represented by the data.

Although the data collected in the urban areas differ slightly between cities, each city had at least accurate data on individual trees and species. Therefore, we could analyze the abundance/frequency of planted NNT in urban areas. Yet, such analysis was not possible based on the forest data. Here, for most tree species, we only had information on whether they occur in forests, but not to what extent and distribution. In addition, based on the data received, we could not further specify the "forest" category. Thus, it was not possible to distinguish between mixed forests, forest plantations or forest trials.

With regard to the invasiveness of NNT, the results must be interpreted with caution: based on the received information by the project partners it remains unknown for most cases whether the reported invasive potentials are based on actual or perceived negative impacts (e.g. expert opinion) as well as which method has been used to assess the risk for each case. Therefore, the numbers only provide a rough indication which species can eventually pose risks to biodiversity or socio - economy. In order to better assess the level of risk associated with these species, comprehensive evaluations based on a consistent method across the Alpine Space would be necessary.

Overall, we had difficulty obtaining distribution data for most of the NNT. Therefore, GIS point shape file format for each species cannot be provided. In any case, accurate distribution data are rather to be expected only for widespread species, such as systematically recorded NNT in the national or regional forest inventories. In this context, we were able to map the distribution of trees well in urban areas, but unfortunately not in forests across the Alpine Space.

4. Outlook

Based on the comprehensive database most commonly reported and promising NNT in the Alpine Space were selected for further literature review on the risks, benefits and management options of using these species (ALPTREES Working package WPT-3) (see Table 2 for overview of species). NNT were included in the list because they either appear useful for climate change adaptation and/or because they may have the potential to be or become invasive. Results will be published in WPT-3. Original NFI data with information on tree species composition for the individual inventory plots could be organized for German and Slovenian forests. Currently, the data is expected to be received from France. These data are being used in the ALPTREES Working Package WPT-2 to develop risk maps based on climate change prediction models.

Further analysis on NNT in cities are planned in the following periods using the collated information of the numerous tree cadastres. For example, relating fitness of NNT (e.g. trunk dimensions) and regional climate data.

Table 2 NNT in the Alpine Space that were selected for further data analysis in the Working Package WP-T3.

1	*Abies nordmanniana subsp. equi-trojani* **f**	17	*Corylus colurna*[1]	34	*Pinus wallichiana*
2	*Abies cephalonica* [1]	18	*Cupressus sempervirens* [1,2]	35	*Platanus acerifolia* [1]
3	*Abies grandis*	19	*Fraxinus pennsylvanica* [3]	36	*Populus x canadensis* [1,3]
4	*Abies nordmanniana*	20	*Ginkgo biloba*	37	*Prunus cerasifera* [1,2]
5	*Acer negundo* [3]	21	*Gleditsia triacanthos* [3]	38	*Prunus serotina* [3]
6	*Acer saccharinum*	22	*Juglas nigra*	39	*Prunus serrulata* **u**
7	*Acer tataricum* [1]	23	*Koelreuteria paniculata* **u**	40	*Pseudotsuga menziesii* [3]
8	*Aesculus x carnea*	24	*Larix kaempferi*	41	*Quercus coccinea* **u**
9	*Ailanthus altissima* [3]	25	*Liquidambar styraciflua*	42	*Quercus rubra* [3]
10	*Alnus cordata*[1]	26	*Liriodendron tulipifera* [3]	43	*Quercus suber* [1]
11	*Broussonetia papyrifera* [3]	27	*Magnolia grandiflora* **u**	44	*Rhus typhina*[3]
12	*Catalpa bignonioides*	28	*Magnolia x soulangeana* **u**	45	*Robinia pseudoacacia* [3]
13	*Catalpa ovata*	29	*Paulownia tomentosa* [3]	46	*Styphnolobium japonicum* **u**
14	*Cedrus deodara*	30	*Picea omorika* [1,2]	47	*Thuja occidentalis*
15	*Cedrus libani*	31	*Picea pungens*	48	*Tsuga canadensis*
16	*Chamaecyparis lawsoniana*	32	*Picea sitchensis* [3]	49	*Ulmus pumila* [3]
		33	*Pinus strobus* [3]		

Occurrence exclusively reported for forests **f** *or for urban areas* **u**
[1] *Native to parts of Europe outside the Alpine Space;* [2] *Archaeophyte;* [3] *Considered (potentially) invasive*

4.1 Acknowledgements

We would like to thank all project partners of the ALPTREES project who helped with data collection and correction. A special thanks goes to Katharina Lapin (BFW), who supported us in editing the taxonomic list of all tree species. Many thanks to Aleksander Marinšek and his team (SFI), for the support with the literature search and corrections of the single tree species.

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