

# A Survey of Alien Dendroflora of Bosnia and Herzegovina

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## ABSTRACT

The accessible literature sources do not give an integrated register of non-native tree species in Bosnia and Herzegovina and western Balkans floras. Therefore, the focus of this study was on an inventory of allochthonous dendroflora in the territory of Bosnia and Herzegovina (B&H) by 2023. Numerous literature sources, the herbarium collection of the National Museum of Bosnia and Herzegovina (SARA) and the authors' field investigations were used to create the allochthonous B&H dendroflora list. The inventory list comprises dendro species of trees, shrubs and lianas. The survey consists of 552 non-native dendro taxa, associated with family, geographic origin, residence time status, degree of naturalization, zone of resistance, and abundance of the investigated taxa. A total of 82 families, 208 genera, and 552 taxa, which included species level, subspecies, varieties, and hybrids were recorded. The B&H allochthonous dendroflora generally originate from Asia (260 taxa) and North America (128), with a significant share of hybrids (81). Only 19 archaeophytes were registered. According to the degree of naturalization, it was observed that as many as 451 taxa are casual and 13 invasive. The non-native dendro species in B&H mainly belong to the USDA Hardiness Zones 4-9, 5-9 and 6-9. The alien dendroflora of B&H includes 152 occasional, 142 rare, 198 abundant and only 60 taxa with massive abundance. The presented results give a detailed insight into the allochthonous dendroflora of B&H, which is also the first such presentation for the Western Balkans.

**Keywords:** allochthonous taxa; archaeophytes; Balkan; hardiness zone; invasive taxa; neophytes; non-native tree (NNT)

## INTRODUCTION

The goods and services provided by ecosystems contribute directly or indirectly to life because they are the basis for human survival at local and global levels (Daly and Farley 2004). Woody plants play a significant role in supplying various services for humans within the framework of providing and regulating ecosystem services and cultural ecosystem services (MEA 2005, Pejchar and Mooney 2009, Haines-Young and Potschin 2018). Non-native tree (NNT) species occupy a significant place among them.

The deliberate (conscious) introduction of plant species from one geographical environment to another began in the Mesolithic period (Nyssen et al. 2016). According to Zagwijn (1994), one of the main reasons for the anthropogenic introduction of woody species was to feed humans and livestock. Ancient trade networks, originally Phoenician, later Greek and Roman, pioneered the introduction of plant species into Europe. All species introduced before 1500 are called archaeophytes, and others are neophytes. Most of

the NNTs that still exist today were introduced to Europe from the end of the 16<sup>th</sup> to the beginning of the 19<sup>th</sup> century (Preston et al. 2004, Nyssen et al. 2016). Certain introduced species expanded their range depending on the optimal ecological conditions without further human influence and became naturalized and sometimes invasive over time (Dodet and Collet 2012), whereby invasive species pose the greatest threat to native biodiversity due to their ability to conquer and alter habitats (Dyderski and Jagodziński 2021). In contrast, humans cultivated some NNTs primarily for their resource potential and a much larger number for horticultural purposes (Castro-Díez et al. 2019, Pötzelsberger et al. 2020, Castro-Díez et al. 2021).

The beginnings of the introduction of NNTs in Bosnia and Herzegovina (B&H) generally took place without an organized and systematic approach. Over the years, the urbanization of the habitats and the market availability of horticultural plants led to a systematic and planned process of plant introduction, which enriched the area with ecologically adapted species (Hadžić et al. 2016). On the

other hand, the introduction of NNTs for forestry purposes aims to create trial areas for the research and cultivation of economically viable species for forest management and utilization. The introduction of NNTs for the formation of forest cultures was initially limited to the period of the Austro-Hungarian Monarchy and the former Yugoslavia. The number of introduced taxa for forest cultures (*Ailanthus altissima* (Mill.) Swingle, *Juglans nigra* L., *Larix decidua* Mill., *Pinus strobus* L., *Pseudotsuga menziesii* (Mirb.) Franco, *Robinia pseudoacacia* L., and *Populus* sp.) was significantly lower compared to ornamental purposes (Šilić 1964, Pintarić 2002).

There is a small number of non-native woody species based on the flora of Bosnia and Herzegovina (Beck-Mannagetta 1903, Beck-Mannagetta 1916, Beck-Mannagetta 1927, Beck-Mannagetta and Maly 1950, Beck-Mannagetta et al. 1967, Beck-Mannagetta et al. 1974, Beck-Mannagetta et al. 1983). In the middle of the 20<sup>th</sup> century, there was an increasing and faster introduction of alien plant taxa, which resulted in the need for systematic recording. The first more comprehensive data (core data, adaptability, decorativeness and justification of use) on the urban dendroflora of larger cities in B&H (Sarajevo, Banja Luka and Mostar) were presented by Stefanović (1955), Fukarek (1959), Šolić (1974), Janjić (1966, 1984, 1992-1996, 1998, 2002) and Ljujić-Mijatović et al. (2000). The inventory and analysis of the dendrological content of urban dendroflora in B&H cities has been intensified in the last two decades (Tomović-Hadžiavić and Šoljan 2006, Stupar 2009, Lukač 2014, Maslo 2014a, 2014b, 2015a, 2015b, Pintarić Avdagić et al. 2015, Hadžić et al. 2016, Maslo 2016a, 2016b, Boškailo et al. 2017, Dervišević et al. 2017, Mešić et al. 2017, Sarajlić and Jogan 2017, Delić et al. 2018, Milanović et al. 2018, Stojanović and Jovanović 2018, Bašić et al. 2019, Đug et al. 2019, Huseinović et al. 2020, Lubarda et al. 2020, Marić et al. 2020, Milanović 2021, Bektić et al. 2022a, Bektić et al. 2022b, Sarajlić et al. 2022, Maslo 2023, Muratović et al. 2023, Lubarda et al. 2024).

According to the available literature sources, there is no integrated register of non-native tree species in B&H. Consequently, the goal of this work was to present a comprehensive inventory of allochthonous dendroflora in the territory of Bosnia and Herzegovina by 2023.

## MATERIALS AND METHODS

### Bosnia and Herzegovinian Geography

Bosnia and Herzegovina is located in Southeast Europe on the Balkan Peninsula (latitudes 42°33'00" – 45°16'30" N, longitudes 15°44'00" – 19°37'41" E) with an area of 51,209 km<sup>2</sup>. It covers three main physical macro-regions: the peri-Pannonian region in the north, the Mountain and Basin region in the central part, and the sub-Mediterranean region in the south. Due to the terrain configuration diversity, there is a wide range of altitudes from 0 m a.s.l. on the Adriatic Sea coast up to 2,386 m a.s.l. in Central Bosnia. According to Köppen-Geiger climate classification, the territory of B&H belongs to Cf, Cs and Df types (Gekić et al. 2022, Trbic et al. 2022), with associated USDA Hardiness Zones ranging from 5a to 9a (<https://www.plantmaps.com>).

### Data Analysis

A comprehensive collection of available literature sources was carried out to create a survey of the allochthonous B&H dendroflora (see References). The data collected were enlarged with information from the herbarium collection of the National Museum of Bosnia and Herzegovina and the authors' field research. The inventory includes dendro species of trees, shrubs and lianas. The subshrubs were not covered in detail, except for a few recorded taxa that often appear in public green areas. Plant names, family affiliation, and synonymy have been checked and harmonized according to the Euro+Med PlantBase (2006+) and the IPNI (International Plant Names Index 2024) nomenclatures. Subspecies and varieties were combined with the type species except in five cases. Common names of taxa in English and vernacular languages were added by Fukarek (1965), Vukičević (1966), Šilić (1990), Borzan (2001), Šilić (2005), Jovanović (2000), Idžojtić (2009), Idžojtić (2013), Cvjetičanin et al. (2016) and Stešević (2020). The origin of interspecies and intergeneric hybrids is given according to Krüssman (1976-78), Krüssman (1983) and POWO (2024). Supplementary File 1 contains taxa names divided into evergreen and deciduous species and arranged alphabetically (by genus and taxon). The corresponding family, geographical origin, introduction period, invasiveness codes, hardiness zones, and species abundance for each taxon were associated. The geographical origin was indicated on a continental level by assigning the following abbreviations: Af-E – East Africa, Af-N – North Africa, Am-N – North America, Am-S – South America, As – Asia, Au – Australia, E – Europe, Eas – Euroasia, H – hybrid. The information on the origin was taken mainly from the following online sources: Plants of the World Online (<https://powo.science.kew.org/>), North Carolina Extension Gardener Plant Toolbox ([https://plants.ces.ncsu.edu/find\\_a\\_plant/](https://plants.ces.ncsu.edu/find_a_plant/)), and European Forest Genetic Resources Programme (<https://www.euforgen.org/species/>). The data from all mentioned online pages were collected from September 2023 to June 2024. Residence time status of taxa accidentally or deliberately introduced to Europe before 1500 were classified as archaeophytes (ARC) and after 1500 as neophytes (NEO) (Pyšek et al. 2002, Preston et al. 2004). The degree of naturalization of taxa was indicated as casual (CAS), naturalized non-invasive (NAT), and naturalized invasive species (INV). Invasive taxa were linked to the corresponding invasiveness code (Đug et al. 2019, Boškailo 2023): A1 – the taxon is of high risk to the environment and is present in the form of isolated populations, A2 – the taxon is of high risk to the environment and has a limited range of distribution, A3 – the taxon is of high risk to the environment and is widely distributed, B1 – the taxon is of moderate risk and it is present in the form of isolated populations, B2 – the taxon is of moderate risk to the environment and has a limited range of distribution, and B3 – the taxon is of moderate risk to the environment and is widely distributed. The USDA hardiness zones, as a dominant factor for assessing the survival of the selected alien plants for cultivation, were attached in Supplementary File 1 and accompanied by literature sources: 1 – North Carolina Extension Gardener Plant Toolbox ([https://plants.ces.ncsu.edu/find\\_a\\_plant/](https://plants.ces.ncsu.edu/find_a_plant/)); 2 – Missouri Botanical Garden

(<https://www.missouribotanicalgarden.org/plantfinder/plantfindersearch.aspx>); 3 – Plants for A Future (<https://pfaf.org/user/>). Data were collected from September 2023 to June 2024. Additionally, the abundance of the investigated taxa was expressed through four categories: massive (M), abundant (A), occasional (O), and rare (R).

## RESULTS AND DISCUSSION

In this study, for the first time, the data of the inventory of allochthonous dendroflora in Bosnia and Herzegovina is presented, which is also the first comprehensive survey in the Western Balkans region. Supplementary File 1 gives data for 82 families (of which 76 are angiosperms), 208 genera (185 angiosperms), and 552 taxa that included the level of species, subspecies, varieties, and hybrids (for angiosperms 411, 1, 4, and 77, respectively).

The most representative families and genera are given in Figure 1. The most genera belonged to Rosaceae (25) and Fabaceae (18). The abundant families with taxa were Rosaceae (125) and Pinaceae (31). Expectedly, plentiful genera were from the family Rosaceae: *Prunus* (22), *Rosa* (18), and *Cotoneaster* (15).

Alien plants mainly inhabit urban zones and comprise between 25% and 50% of European urban flora (Pyšek 1998, Tretyakova et al. 2021). Data on the number of non-native species of higher plants in Europe are not uniform. Consequently, Roy et al. (2020) state that 56% (6778) of introduced taxa belong to spermatophytes in Europe. At the same time, Haubrock et al. (2023) state that there are 5136 allochthonous vascular plants in the European Union, while Kalusová et al. (2024) recorded 7335 taxa in total (6774 species and 561 hybrids and cultivars). All three B&H surrounding countries recorded a lower number of alien species (Serbia 186, Croatia 182, and Montenegro 47) (Kalusová et al. 2024). Unfortunately, data on the

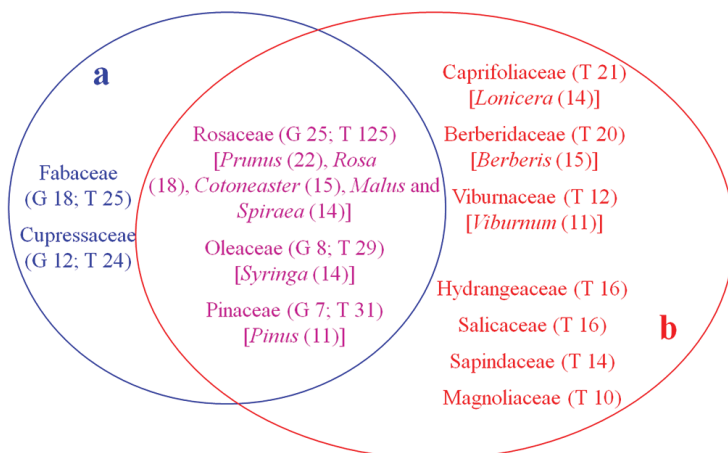
contribution of alien dendro taxa or complete checklists are unavailable except for Croatia (Nikolić 2015).

According to Redžić et al. (2008), the high degree of heterogeneity of Bosnia and Herzegovina's habitats enables the penetration and survival of many non-native taxa. The authors estimate that there are more than 500 non-native species (11.12% of flora of B&H) in Bosnia and Herzegovina, many of which have adapted to natural habitats. In the overview of alien plants of Europe, Kalusová et al. (2024) for B&H state only 252 alien species. Our research, 15 years later, indicates a significant increase in the number of allochthonous species, where only non-native dendro taxa (552) comprise 12.27% of the flora of Bosnia and Herzegovina.

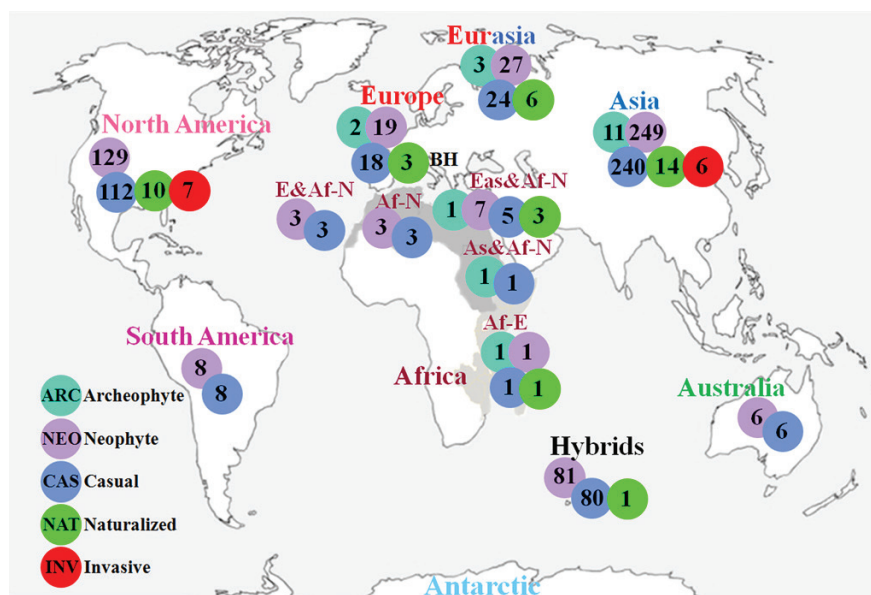
Our results confirm the conclusions of some authors that the requirements for the expansion of urban zones and green areas, specific environmental conditions in urban habitats, developed transport networks, availability of horticultural plants, and social-economic impacts have led to a significantly increased share of alien species in the local floras (Pyšek 1998, Pyšek et al. 2002, Tretyakova et al. 2021, Sirbu et al. 2022).

Figure 2 shows that allochthonous dendroflora in B&H generally originates from Asia (260 taxa) and North America (128), with a significant share of hybrids (81). Of the total taxa recorded, only 19 (one gymnosperm) were archaeophytes. Of these, 11 taxa are naturalized in B&H primarily due to the significant resource potential related to different human needs (e.g. *Larix decidua* Mill., *Cydonia oblonga* Mill., *Ficus carica* L., *Lavandula angustifolia* Mill., *Morus alba* L., *Morus nigra* L., *Prunus cerasifera* Ehrh., *Prunus cerasus* L., *Prunus domestica* L., *Punica granatum* L. and *Ricinus communis* L.).

Among the neophytes, 13 of them (seven North American and six Asian) are invasive in Bosnia and Herzegovina. Below, we give a comparative overview of invasive dendro taxa in B&H and the neighboring countries (Table 1).



**Figure 1.** The Venn diagram represents families with both (a) more than five genera (G) and 10 taxa (T), and (b) ten or more taxa (T). In both cases the genera with more than 10 taxa are named.



**Figure 2.** Geographical origin of allochthonous dendro species occurring in Bosnia and Herzegovina (BH). Some species have multiple continental origins. The following abbreviations indicate geographical origin at the continental level: Af-E – East Africa, Af-N – North Africa, Am-N – North America, Am-S – South America, As – Asia, Au – Australia, E – Europe, Eas – Euroasia.

**Table 1.** Overview of registered invasive dendro taxa in B&H (with associated invasiveness codes) and in the neighboring countries. The total number of invasive taxa is given in parentheses (Boškailo 2023, Korda et al. 2023).

No.	Taxon	Invasion status in B&H	B&H (13)	Cro (7)	MNE (6)	Srb (15)
1.	<i>Acer negundo</i> L.	A2	☑	☑	☑	☑
2.	<i>Ailanthus altissima</i> (Mill.) Swingle	A3	☑	☑	☑	☑
3.	<i>Amorpha fruticosa</i> L.	A2	☑	☑	☑	☑
4.	<i>Broussonetia papyrifera</i> (L.) Vent.	A2	☑	☑	☑	☑
5.	<i>Bryonia cretica</i> subsp. <i>dioica</i> (Jacq.) Tutin					☑
6.	<i>Buddleja davidii</i> Franch.	B3	☑			
7.	<i>Celtis occidentalis</i> L.					☑
8.	<i>Fallopia baldschuanica</i> (Regel) Holub	B1	☑			☑
9.	<i>Fraxinus americana</i> L.					☑
10.	<i>Fraxinus pennsylvanica</i> Marshall	B1	☑	☑		
11.	<i>Lycium barbarum</i> L.					☑
12.	<i>Melia azedarach</i> L.	B2	☑			
13.	<i>Parthenocissus quinquefolia</i> Planch.	B3	☑	☑		☑
14.	<i>Prunus padus</i> L.					☑
15.	<i>Prunus serotina</i> Ehrh.	A1	☑			☑
16.	<i>Pueraria montana</i> (Lour.) Merr.	A2	☑			
17.	<i>Rhus typhina</i> L.	B3	☑			
18.	<i>Robinia pseudoacacia</i> L.	A3	☑	☑	☑	☑
19.	<i>Tamarix dalmatica</i> B.R. Baum				☑	
20.	<i>Ulmus pumila</i> L.					☑
21.	<i>Vitis riparia</i> Michx.					☑

B&H – Bosnia and Herzegovina, Cro – Croatia, MNE – Montenegro, Srb – Serbia.

According to different authors (Preston et al. 2004, Pyšek et al. 2004, Nyssen et al. 2016), most of the present NNTs were introduced in the period from the 16<sup>th</sup> until the 18<sup>th</sup> century in Europe. Kalusová et al. (2024) highlight that European alien flora comprises 20.4% of taxa from temperate Asia, 19.6% from temperate Europe, 19.0% from the Mediterranean region, and 16.0% from the Americas, with 77.2% exclusively neophytes. The most neophytes have origins in temperate Asia, temperate Europe and the Americas. On the contrary, archaeophytes mainly originated from the Mediterranean region, the Middle East and Europe (Pyšek et al. 2002, Kalusová et al. 2024). Regardless of the introduction period and geographical origin, those NNTs that were functionally adapted to the urban environment have survived (Knapp et al. 2008).

Kalusová et al. (2024) present comparative data about the residence time of allochthonous flora for Bosnia and Herzegovina and its neighbours: B&H (ARC 70, NEO 170 species, ARC+NEO 12), Croatia (ARC 17, NEO 134 species, ARC+NEO 34), Montenegro (NEO 49), and Serbia (no data). The number of allochthonous dendro taxa could be recalculated only for the Croatian flora, which comprises 46% Asian and 25% North American taxa. Of the 501 taxa in Croatian allochthonous dendroflora, 95% are neophytes (Nikolić 2015). The similarity of the dendro alien taxa distribution in the B&H and Croatian floras can be observed, with 1.5% fewer archaeophytes in the flora of Bosnia and Herzegovina.

Kalusová et al. (2024) state that 11,973 CAS alien species, 1,593 non-separated CAS and NAT alien species, 8,724 NAT alien species, 1,180 NAT and INV alien species, and 2,664 INV alien species exist in Europe. The same

authors gave the overview of the alien species numbers for the previously mentioned categories for B&H (CAS 135, NAT 62 species, INV 55), Serbia (CAS+NAT 34, INV 152), Croatia (NAT 22, INV 63 species), and Montenegro (INV 47 species). Our results showed that only in alien dendroflora of B&H 451 CAS, 33 NAT and 13 INV taxa are registered.

Due to faster growth and resistance to climate change, pathogens and pests, non-native woody species are often preferred over autochthonous ones, especially in tree planting programs (Brus et al. 2019, Vítková et al. 2020). Additionally, to sustainably manage the cultivation of non-native tree species through a wide range of ecosystem services and due to pronounced climate changes, it is desirable to be familiar with the hardiness zones for each taxon. Therefore, to help local growers and hobbyists, these data were also included wherever possible (Supplementary File 1). Although the USDA Hardiness zones from 5a to 9a are associated with B&H (<https://www.plantmaps.com>), our results indicated that the most non-native dendro species in B&H belong to the HZs 4-9, 5-9 and 6-9 (Table 2).

Although the area of Bosnia and Herzegovina is characterized by exceptional ecological, geomorphological and hydrological heterogeneity, sustainable cultivation management is not presented to a large extent. Our field research showed that people's preferences, urban or suburban planting micro-locations, socioeconomic status, and availability on the local markets most often determined the selection and the number of planted non-native species. According to the abundance of observed individuals, out of a total of 552 listed non-native woody species in Bosnia and Herzegovina (Supplementary File 1), 198 of them are abundant (A), 142 are rare (R), 152 are occasional (O), and only 60 are massive (M).

**Table 2.** Distribution of non-native dendro species in Bosnia and Herzegovina according to the USDA Hardiness Zones. No data could be found for 83 taxa.

Hardiness Zones*		4	5	6	7	8	9	10	11	12
Zones*	Temp. range (°C)	-34.4 to -28.9	-28.9 to -23.3	-23.3 to -17.8	-17.8 to -12.2	-12.2 to -6.7	-6.7 to -1.1	-1.1 to 4.4	4.4 to 10.0	10.0 to 15.6
2	-45.6 to -40.0		1	2	9	5	2			
3	-40.0 to -34.4				16	24	18	1		
4	-34.4 to -28.9	1		1	15	<b>71</b>	<b>31</b>	4		
5	-28.9 to -23.3			1	12	<b>51</b>	<b>38</b>	3		
6	-23.3 to -17.8				1	12	<b>31</b>	5	3	
7	-17.8 to -12.2					3	11	10	4	
8	-12.2 to -6.7						5	9	1	
9	-6.7 to -1.1						1		6	1
10	-1.1 to 4.4									1

\*USDA Hardiness Zones are based on the average annual extreme minimum winter temperature (°C) and are listed in the table with the corresponding colors. Values from more than 30 taxa for corresponding HZs are in bold.



## CONCLUSIONS

The presented results provide data for future sustainable planning of alien dendro taxa introduction and maintenance, including monitoring of potentially invasive species spreading. In conclusion, the list of alien dendroflora in B&H is not final and complete. Continuous monitoring and regular updates are necessary for a comprehensive understanding of the relevant situation.

## Author Contributions

NB, FP, EM conceived and designed the research, NB, EM and AB carried out the field work, NB, EM and FP processed the data and performed the statistical analysis, NB supervised the research and helped to draft the manuscript, FP and EM wrote the manuscript.

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The authors dedicate this article to the memory of deceased professor Nikola Janjić (University of Sarajevo- Faculty of Forestry, Bosnia and Herzegovina).

## Conflicts of Interest

The authors declare no conflicts of interest.

## Supplementary Materials

**Supplementary File 1** - The list of allochthonous dendroflora in Bosnia and Herzegovina with the corresponding family, vernacular and English names, geographical origin, period of introduction, current invasion status/code of invasiveness, US plant hardness zone, and species abundance.

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