Original scientific paper
DOI: /10.5513/JCEA01/27.2.4898
Journal of Central European Agriculture, 2026, 27(2), p.532-544

Global distribution and invasive potential of *Arundo donax* and *Paulownia* spp.: a case study in Slovakia

Globálne rozšírenie a inváz ny potenciál *Arundo donax* a *Paulownia* spp.: prípadová štúdia na Slovensku

Žaneta PAUKOVÁ (✉), Martin HAUPTVOGL

Institute of Sustainable Regional and Local Development, Faculty of European Studies and Regional Development, Slovak University of Agriculture, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia

✉ Corresponding author: zaneta.paukova@uniag.sk

Received: June 13, 2025; accepted: March 5, 2026

ABSTRACT

The cultivation of fast-growing plant species for biomass production is frequently promoted in European policies aimed at enhancing energy security and sustainability. Still, the role of biomass varies widely across EU regions. However, some of these species pose ecological risks due to their invasive potential. The recorded global distributions of *Arundo donax* and *Paulownia* spp. exhibit similar patterns, with the highest concentrations occurring in Europe and North America, indicating widespread introduction and suggesting ongoing naturalization of both species across many regions beyond their native ranges. This study evaluates the invasive potential of the fast-growing perennial grass *Arundo donax* and two fast-growing woody taxa of *Paulownia*, the clone R112 and hybrid 9501. These taxa are cultivated at the research base of the Slovak University of Agriculture in Nitra (village Kolíňany), located in western Slovakia. A nine-year field study revealed that *Arundo donax* presents a high invasion risk, with a potential invasion score of 18, primarily due to its aggressive vegetative spread and its ability to form dense stands that displace native vegetation. Despite the absence of generative reproduction, its rapid vegetative propagation underscores the need for active monitoring. Similarly, a ten-year evaluation of *Paulownia* clone R112 and hybrid 9501 yielded potential invasion scores of 15 and 13, respectively. While the studied *Paulownia* plants did not produce viable seeds, they exhibited vigorous vegetative reproduction through root suckers. However, future hybridisation with *Paulownia tomentosa* remains a concern, as this could result in viable seed production and facilitate further spread. The study thus highlights the importance of long-term monitoring and management of these species to prevent uncontrolled expansion and mitigate associated ecological risks.

Keywords: *Arundo donax*, *Paulownia* spp., invasion potential, fast-growing plant

SAŽETAK

Pestovanie rýchlorastúcich druhov rastlín na produkciu biomasy je často podporované v európskych politikách zameraných na zvyšovanie energetickej bezpečnosti a udržateľnosti, ale postavenie biomasy je v rôznych regiónoch EÚ veľmi heterogénne. Niektoré z týchto druhov však predstavujú ekologické riziká v dôsledku inváz neho potenciálu. Zaznamenané globálne rozšírenie *Arundo donax* a *Paulownia* spp. vykazuje podobné vzorce, pričom najväčšie ohniská rozšírenia sa vyskytujú v Európe a Severnej Amerike, čo poukazuje na ich široké introdukovanie a naznačuje prebiehajúcu naturalizáciu týchto druhov v mnohých oblastiach mimo ich pôvodného areálu. Táto štúdia hodnotí inváz ny potenciál rýchlorastúcej trvácej trávy *Arundo donax* a dvoch rýchlorastúcich drevín *Paulownia* klonu R112 a hybridu 9501. Tieto taxóny sa pestujú na výskumnej báze Slovenskej poľnohospodárskej univerzity v Kolíňanoch pri Nitre na západnom Slovensku. Deväťročná terénna štúdia ukázala, že *Arundo donax* predstavuje vysoké riziko inváz ie s potenciálnym skóre inváz ie 18, predovšetkým kvôli jej agresívnemu vegetatívnemu šíreniu a schopnosti vytvárať husté

porasty, ktoré vytláčajú pôvodnú vegetáciu. Napriek absencii generatívneho rozmnožovania jej rýchle vegetatívne rozmnožovanie poukazuje na potrebu aktívneho monitorovania. Podobne, desaťročné hodnotenie *Paulownia* klonu R112 a hybridu 9501 prinieslo potenciálne skóre invázie 15 a 13. Zatiaľ čo sledované rastliny *Paulownia* neprodukovali životaschopné semená, vykazovali intenzívne vegetatívne rozmnožovanie prostredníctvom koreňových výmlatkov. Rizikom však zostáva možná budúca hybridizácia s *Paulownia tomentosa*, ktorá by mohla viesť k tvorbe životaschopných semien a tým podporiť ďalšie šírenie. Štúdia tak zdôrazňuje význam dlhodobého monitorovania a manažmentu týchto druhov s cieľom predísť ich nekontrolovanému šíreniu a zmierniť s tým spojené ekologické riziká.

Kľúčové slová: *Arundo donax*, *Paulownia* spp., inváznny potenciál, rýchlo rastúca rastlina

INTRODUCTION

A species classified as invasive, or invading, is a non-native species that exhibits aggressive or damaging behaviours in a new area beyond its original range (Pauková, 2021). Non-native species, also referred to as alien species, are those that do not naturally occur in Slovakia and were either intentionally introduced or have spread from other regions (Eliáš, 2023). Invasive species are a subset of non-native species that can rapidly spread and cause significant disruption to local ecosystems, including native plant and animal populations as well as habitats. These species are often introduced to Europe from regions such as the Americas, Asia, or other parts of the world (ŠOP SR, 2024). Some non-native species, including certain fast-growing tree and herb species, have the potential to become invasive under favourable conditions. Although these species may not yet pose a significant threat to biodiversity, they could spread over time and develop invasive characteristics (Richardson et al., 2000).

When assessing invasive behaviour, several factors must be considered. In Slovakia, specific regulations govern the planting of species such as *Arundo donax* (giant reed) and various *Paulownia* clones and hybrids. These species require approval from state nature protection authorities, as they are not listed among non-native species that can be planted without prior consent (Decree No. 170/2021 Coll., Government Regulation No. SR 449/2019 Coll., Commission Regulation EU No 2019/1262). Similarly, the planting and cultivation of non-native species in built-up areas exceeding 1,000 m² also require authorisation (Act No. 150/2019 Coll.).

For example, *Arundo donax* is a non-native species introduced to Europe and commonly used as an ornamental plant. While it has recognized economic benefits, such as applications in biofuel production and phytoremediation (Kassem et al., 2024), it also poses a significant risk of becoming invasive. The ecological threat of *Arundo donax* is exacerbated by its aggressive vegetative reproduction and rapid spread across landscapes, which can disrupt native biodiversity and ecosystems. *Arundo donax* is listed among the world's top 100 invasive plant species, and its propagation is prohibited in some countries (Velez-Gavilan, 2024). It is already invasive on six continents and in at least 99 countries. The species poses a continued risk of further spread due to ongoing human use in construction, textiles, and biofuel production. Regions such as the equatorial tropics and subtropical grasslands in South America, Africa, and Asia are particularly vulnerable to future invasions (Goolsby et al., 2023).

Over the past two decades, *Paulownia* spp. has been widely promoted as a renewable source of timber and wood chips (Negruşier et al., 2025). The research has increased due to the growing interest in the plant application for biofuel production and phytoremediation. The wood is also used in pulp and other wood processing industries, the creation of wood composites and biopolymers (Jakubowski et al., 2018; Jakubowski, 2022; Lugli et al., 2023). The trees of the *Paulownia* genus have also been studied as a source of promising chemical compounds with various biological activities (e.g., antioxidant, anti-inflammatory, antiproliferative, antibacterial, antiviral, neuroprotective, and hepatoprotective activities) (Sławińska et al., 2023).

Paulownia is a pioneer species, rapidly colonizing disturbed and open habitats (Williams and Wang, 2021). The European and Mediterranean Plant Protection Organization (EPPO, 2021) has included *Paulownia tomentosa* on its Alert list to gather further information on its impact on native ecosystems in Europe. *Paulownia tomentosa* is classified as an invasive species in many countries (Essl, 2007; Snow, 2015) and has been identified as a species with potentially high environmental risk in the Czech Republic (Pergl et al., 2016), and it is classified there as a "rare invasive species" (Pyšek et al., 2002, 2012, 2022). In Switzerland, *Paulownia tomentosa* is classified as a potentially invasive species (FOEN, 2002). Additionally, *Paulownia* clones and hybrids have been assessed for their invasive potential in Slovakia (Jankovič et al., 2016; Maľová et al., 2016; Jureková et al., 2019; Pauková et al., 2022; Jureková et al., 2022). Gojdičová et al. (2002) classified *Paulownia tomentosa* among non-native, invasive, and expansive vascular plants, indicating that it frequently exhibits invasive tendencies. Medvecká et al. (2012) classified it as a naturalized species that regularly and persistently establishes viable populations in the wild without direct human intervention, thereby integrating into local ecosystems. Even if most works are devoted only to the most widespread species, *Paulownia tomentosa*, it can be assumed that other species and hybrids of *Paulownia* probably have a similar potential for spreading (Kadlec, 2024a, 2024b).

The main aim of this study is to assess the invasive potential of the fast-growing perennial grass *Arundo donax* and two *Paulownia* taxa (clone R112 and hybrid 9501) cultivated in experimental plots at the research sites of the Slovak University of Agriculture in Kolíňany near Nitra in western Slovakia. In addition, the study compiles and visualizes global and European distribution data for *Arundo donax* and *Paulownia* spp. using publicly available databases (GBIF, iNaturalist, and CABI) to provide a broader spatial context.

Research hypothesis - despite the absence of viable generative reproduction, the fast-growing biomass species *Arundo donax* and *Paulownia* (clone R112 and hybrid 9501) exhibit significant invasive potential due to their vigorous vegetative propagation, which may enable their persistence, spread, and possible naturalization in non-native environments.

MATERIALS AND METHODS

The studied plants included *Arundo donax* (common reed) and *Paulownia* clone R112 (*Paulownia elongata* × *Paulownia fortunei*) and hybrid 9501 (*Paulownia* Pao Tong × *Paulownia* Shan Tong). *Arundo donax* is one of the most robust perennial grasses from the *Poaceae* family. *Paulownia* is a genus of fast-growing, deciduous trees belonging to the *Paulowniaceae* family.

A field trial of *Arundo donax* was established at the research site of the Slovak University of Agriculture in Nitra (SUA) in the village of Kolíňany, western Slovakia, in 2016. The *Paulownia* experimental plot was established in 2014 (clone R112) and 2016 (hybrid 9501) at a research site of the Slovak University of Agriculture in the close vicinity of the *Arundo donax* plot (Figure 1).

The primary soil type in the area is classified as a medium-heavy soil (Demo, 2013). The location belongs to a moderately warm and moderately humid lowland climate region. In recent climatological data, the average annual air temperature in Nitra is around 10 °C (SHMÚ, 2025). Before the establishment of both experiments, inorganic NPK fertiliser was applied (100 kg/ha N, 60 kg/ha K, and 30 kg/ha P); no herbicides were applied. *Arundo donax* seedlings were produced using *in vitro* technology under laboratory conditions at Arundo Celluloz Farming Kft., Hungary. The *Paulownia* seedlings were cultivated *in vitro* in the laboratories of the University of Alicante (Spain). Before planting, all the seedlings were acclimatised in the greenhouse of the SUA Botanical Garden in Nitra. (Pauková and Jureková, 2017, 2018, 2019; Pauková et al., 2022).

The invasive potential of the two studied species was assessed according to the methodology for determining the invasive potential for permanent plant species (Mooschová, 2006). The following seven parameters were evaluated: number of seeds per plant, plant height, plant

density, means of generative reproduction, vegetative reproduction, and behaviour of the species in the country of origin. Each of the seven parameters received a score between 0 and 5 points, resulting in a maximum total of 35 points. The invasion risk assessment scale was as follows:

- 0 point: no data was recorded,
- 1 – 10 points: low risk of invasion,
- 11 – 17 points: possible risk of invasion,
- 18 or more points: high risk of invasion.

To create maps on the global (grid cell 200 × 200 km) and European (grid cell 50 × 50 km) occurrence of *Arundo donax* and *Paulownia* spp., records were obtained from three major biodiversity databases: the Global Biodiversity Information Facility (GBIF), iNaturalist, and the Centre for Agriculture and Bioscience International (CABI). The GBIF dataset was first filtered to remove records explicitly sourced from iNaturalist (GBIF contains data from various sources, and iNaturalist is one of them). The filtered GBIF data were then combined with the full iNaturalist and CABI datasets.

This procedure resulted in a merged dataset containing 93,906 unique recorded occurrences globally for *Arundo donax* and 70,171 occurrences for *Paulownia* spp. While some data may still be missing or overlapping due to limitations in coordinate precision or metadata availability, this integrated dataset offers broader spatial coverage than any individual source. The distribution maps of *Arundo donax* and *Paulownia* spp. covering global and European spatial extents were created in QGIS (version 3.38.2).

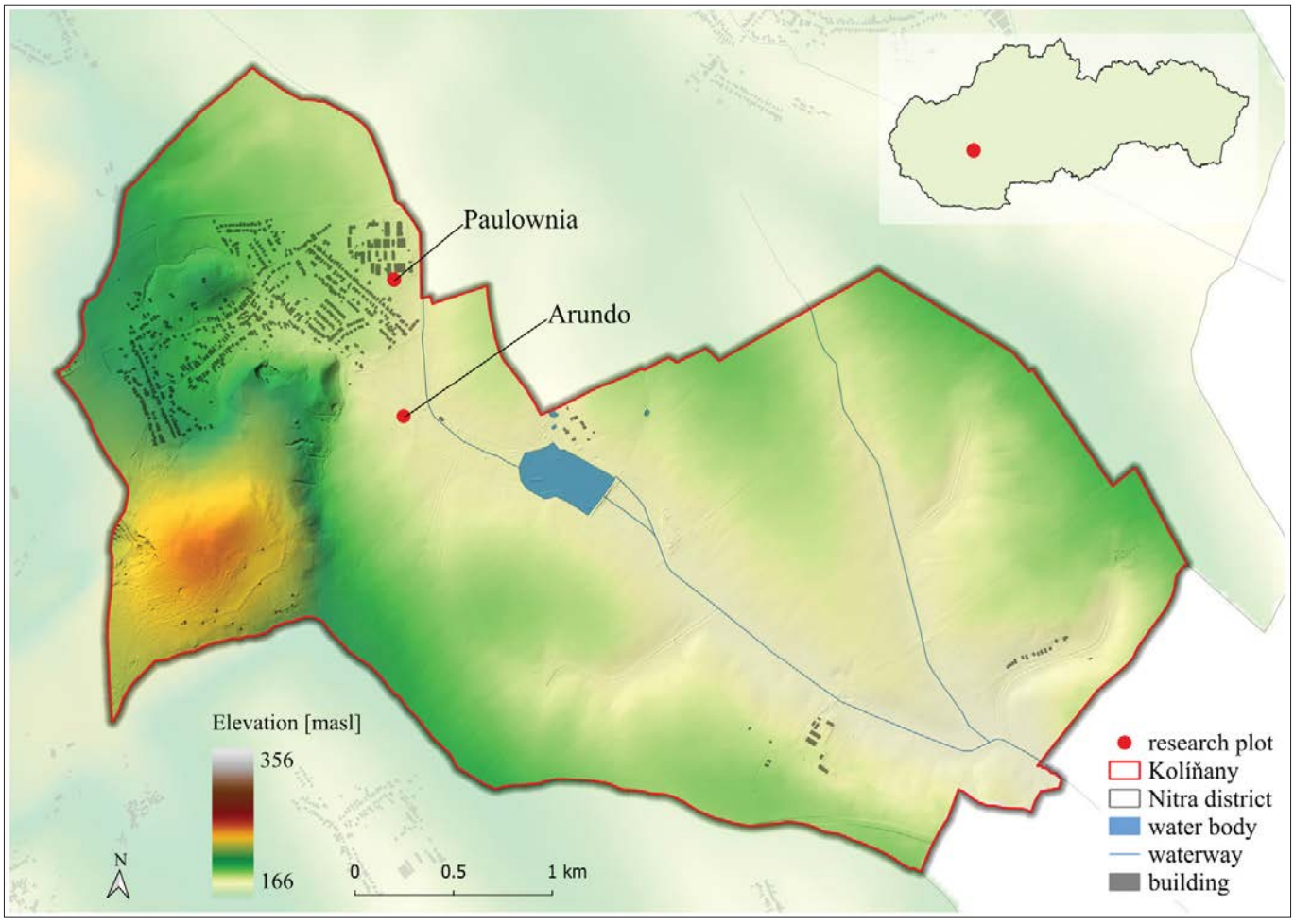

Figure 1. Research plots in Kolíňany, western Slovakia

RESULTS AND DISCUSSION

Distribution of Arundo donax

The global distribution of *Arundo donax* reveals a widespread presence, with notable occurrences in temperate and subtropical regions. Overall, the data illustrate that *Arundo donax* thrives in warm, riverine or coastal environments and has successfully established itself in diverse regions across multiple continents. The highest number of occurrences was recorded in Europe (60% of all global occurrences) and North America (almost 26%). The highest densities of the species are reported in Southern Europe, followed by the eastern United States. Many occurrences were also recorded in southeastern Australia, eastern Asia, the Middle East, southern Africa and South America (Figure 2).

In Europe, the highest concentration zones are in the Mediterranean basin, especially in southern France, southeastern Spain, Portugal and northern Italy. These regions contribute to over 50% of the globally recorded occurrences. Two countries alone, namely France (23%) and Spain (20%), represent 43% of all global occurrences. The species is much less prevalent in Eastern and Northern Europe (Figure 3).

According to Jiménez-Ruiz et al. (2021), *Arundo donax* originated in subtropical Asia and is invasive in other warm regions worldwide, especially in degraded riparian areas. The high density in the Mediterranean region is due to its introduction as an ornamental plant, mainly cultivated in gardens and parks, but also for use in agriculture, erosion control and construction since ancient times. It has become naturalized in several freshwater habitats and in disturbed areas, especially around the Mediterranean Sea, where it grows spontaneously (Gubišová et al., 2016; Antal, 2018; Jimenes-Ruiz, 2021; Goolsby et al., 2023). *Arundo donax* was also introduced to many countries worldwide as a promising bioenergy crop with phytoremediation potential, and many field studies and experiments have been conducted across a wide range of countries such as Italy, Spain, Greece, the USA and China (Jámbor and Török, 2019).

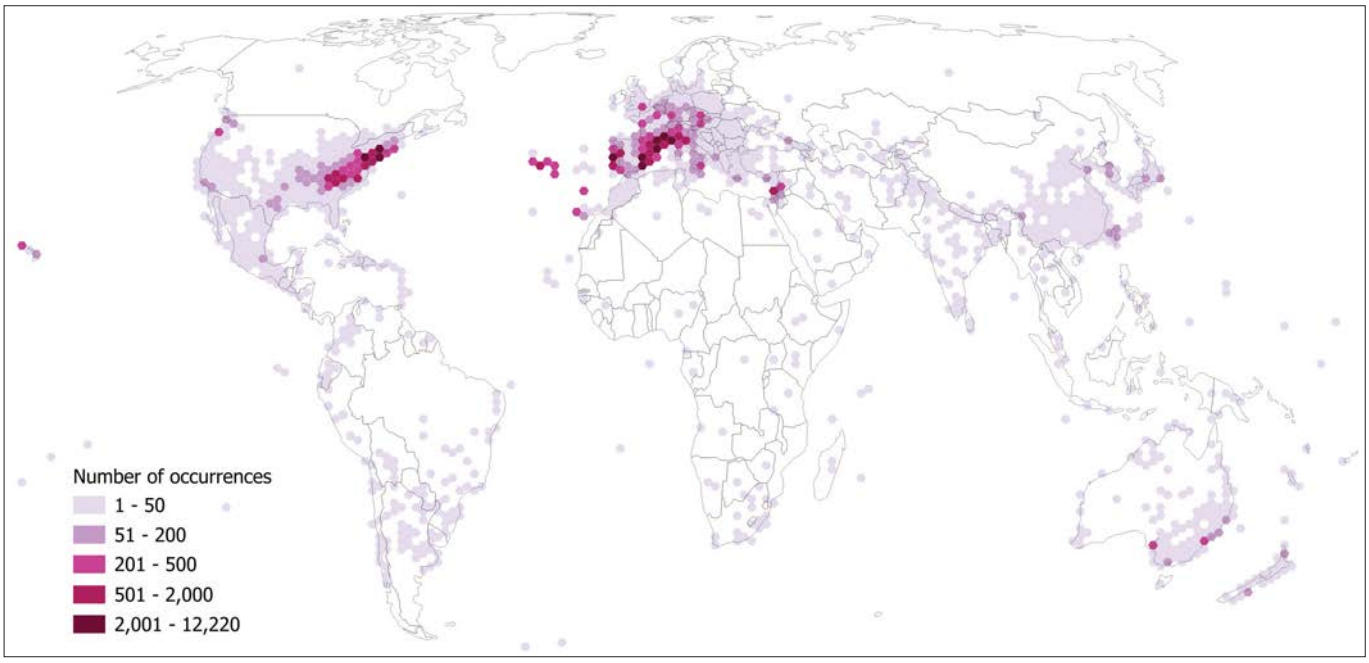

Figure 2. Distribution of *Arundo donax* in the world (GBIF, 2025a; iNaturalist, 2025a; CABI, 2025a)

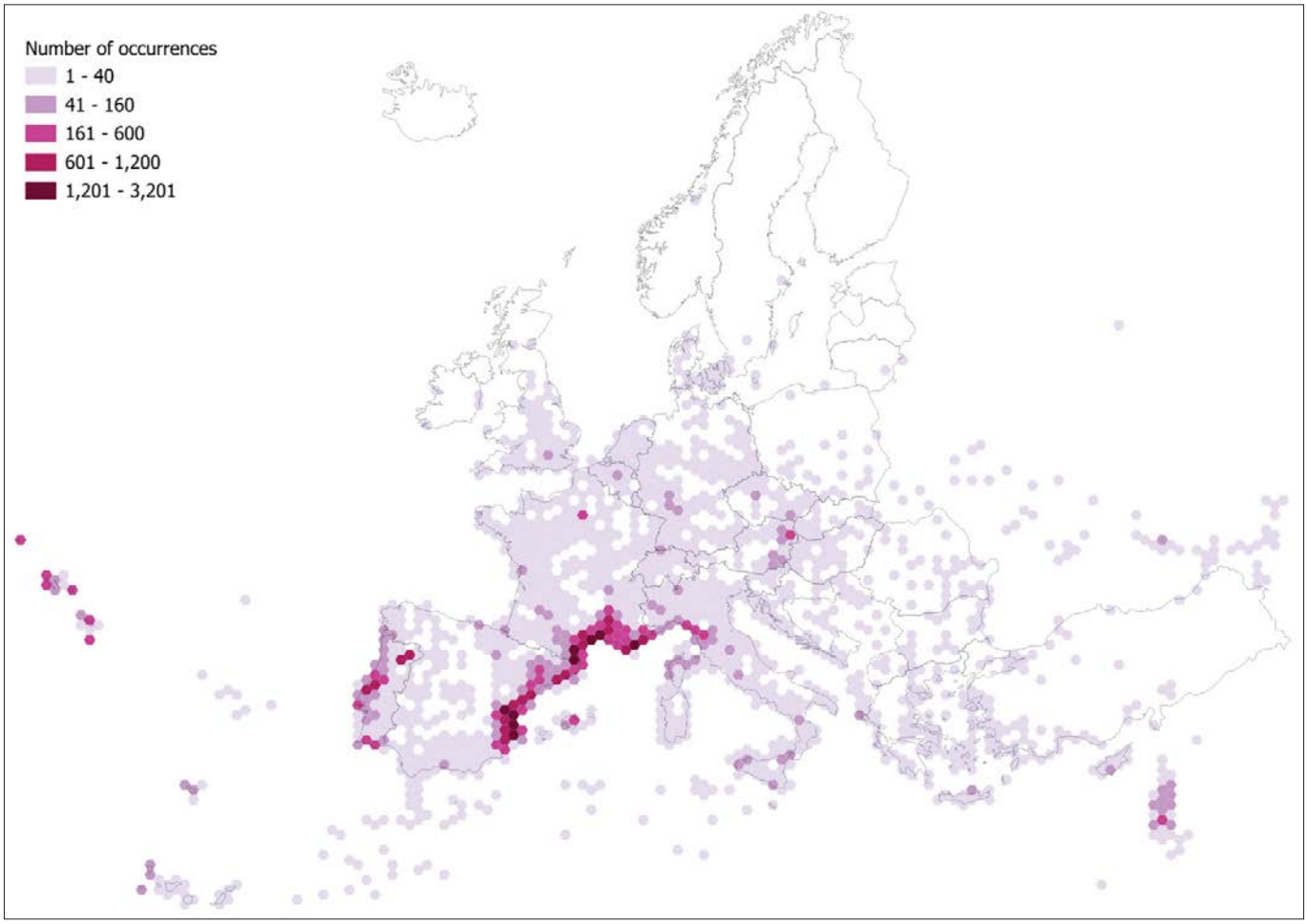

Figure 3. Distribution of *Arundo donax* in Europe (GBIF, 2025a; iNaturalist, 2025a; CABI, 2025a)

Distribution of Paulownia spp.

The global distribution of *Paulownia* spp. occurrences reveals distinct regional patterns and closely resemble the global distribution of *Arundo donax*. Based on recorded occurrence data, the highest concentrations are found in Europe and North America, where the species has been introduced (Essl, 2007; Badalamenti, 2019; Pyšek et al., 2022). These two regions account for most of the *Paulownia* spp. occurrences with 51% and almost 34% of all recorded global occurrences in Europe and North America, respectively. The highest densities are observed mainly in Central Europe and the eastern United States around the Appalachian region. Other regions with relatively high densities include parts of East Asia, especially South Korea, Japan and eastern China. Many records are found in the Middle East, South America, eastern Australia, and New Zealand (Figure 4).

The first *Paulownia* trees (*Paulownia tomentosa*), native to central and western China, were introduced to Central Europe in 1834 as ornamental trees (Williams, 1983). In Slovakia, *Paulownia tomentosa* has been grown as an ornamental tree since around 1870 (Mártonfi, 1997). Currently, the total number of mature individuals predominantly found in parks is estimated to slightly exceed 100 across the country. In Slovakia, both ornamental and plantation uses of *Paulownia* spp. have been documented, including historical specimens and recent hybrid plantations (Mártonfi, 1997; Barančok et al., 1999; Pástor et al., 2022).

Europe is the region with the most recorded *Paulownia* spp. occurrences, as well as the highest densities. Similar to *Arundo donax*, these findings highlight the extensive introduction and possible naturalization of *Paulownia* spp. outside their native range.

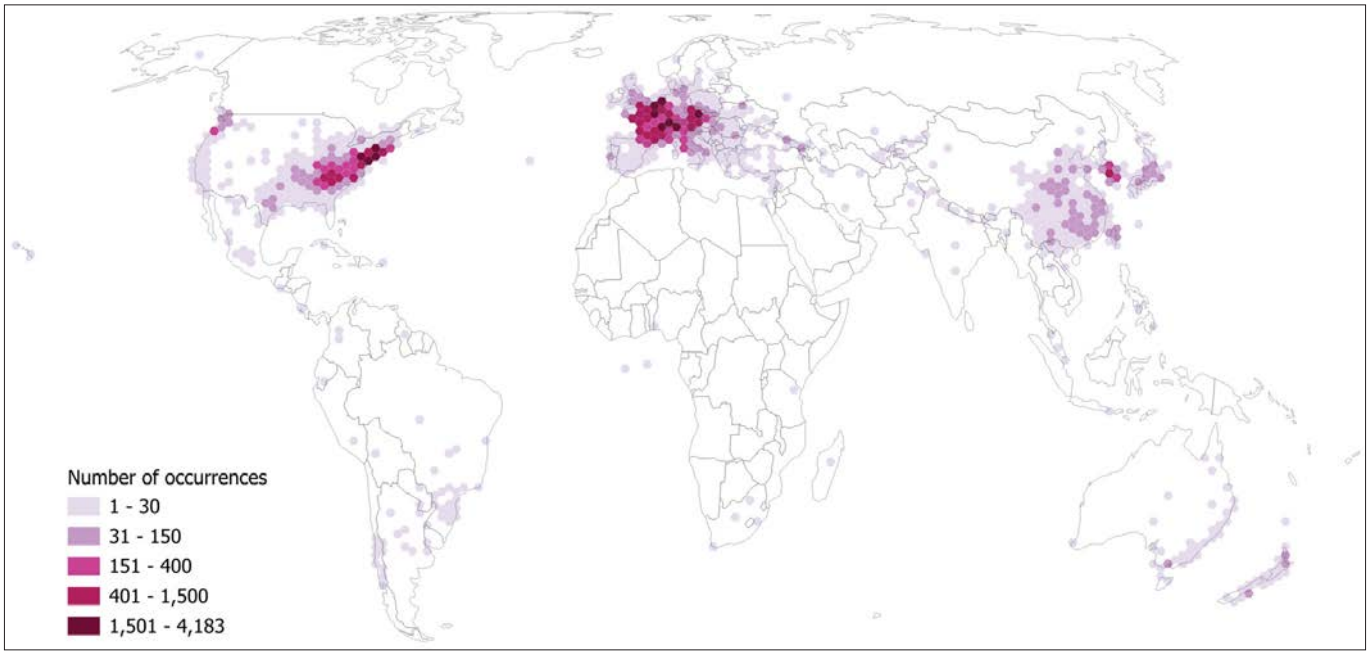

Figure 4. Distribution of *Paulownia* spp. in the world (GBIF, 2025b; iNaturalist, 2025b; CABI, 2025b)

Particularly dense clusters occur in France (21% of all global occurrences), Switzerland, Belgium, and the Czech Republic. These four countries account for 35% of global *Paulownia* spp. occurrence. Other notable concentrations include northern Italy, Austria, the Netherlands, southern England and Germany (Figure 5).

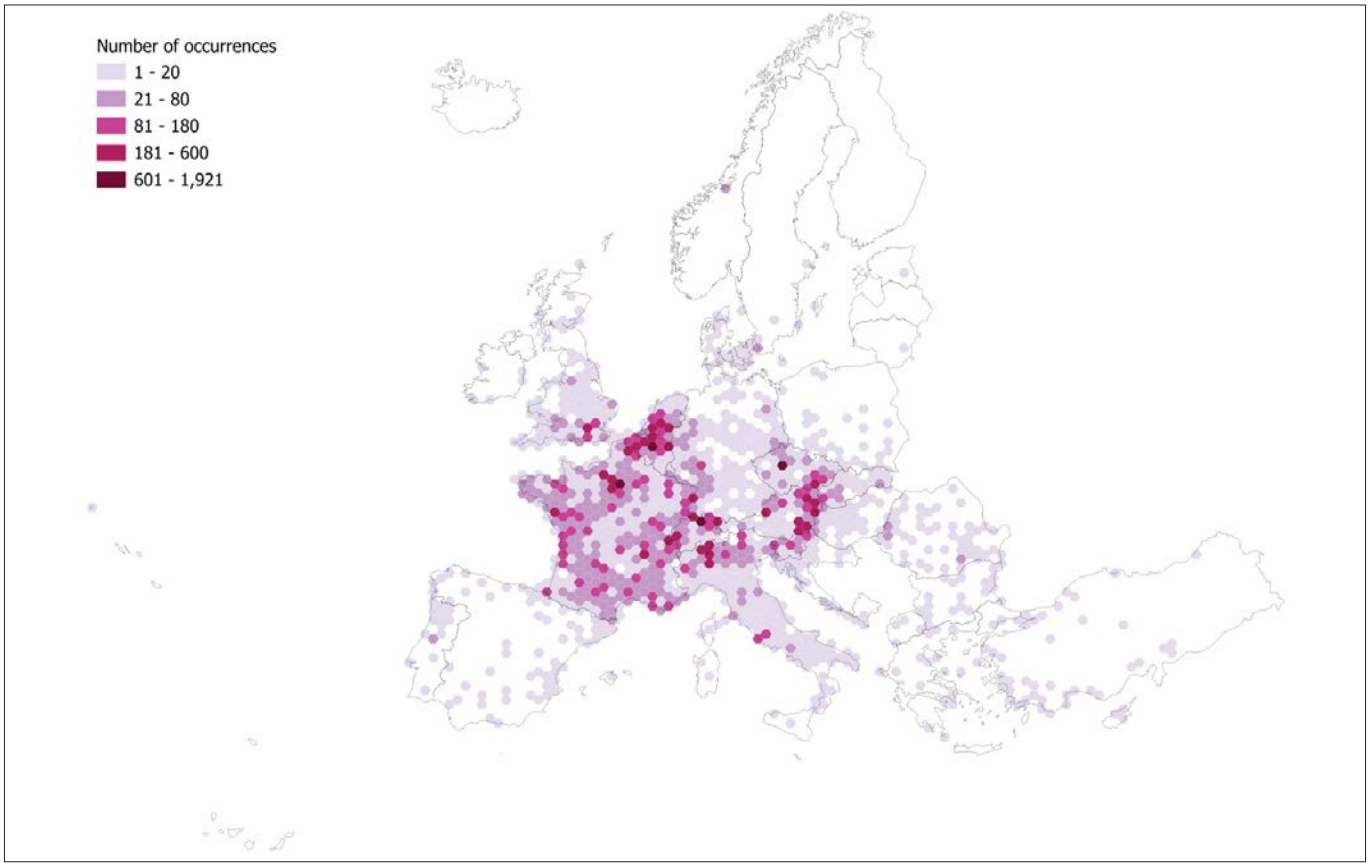

Figure 5. Distribution of *Paulownia* spp. in Europe (GBIF, 2025; iNaturalist, 2025; CABI, 2025)

Although *Paulownia* spp. has demonstrated potential for bioenergy, timber production, carbon sequestration and other uses (Yadav et al., 2013; Ghazzawy et al., Jakubowski, 2022; 2024), their rapid growth rate and ability to colonize disturbed areas have raised concerns about invasive tendencies in non-native environments (Bai et al., 2019; Pyšek et al., 2022).

So far, due to the invasive potential, only some hybrids have been accepted into mass cultivation. Plantations of *Paulownia* hybrids have been established in southern Europe, particularly in Spain, Portugal, Italy, and the Balkans, as well as in Middle Eastern countries such as Turkey and Iran. These countries have much better conditions than those further north (Jakubowski, 2022). While the best growth has been achieved in the Middle East and Southern Europe, ongoing experiments in Central Europe are still adapting cultivation techniques to regional conditions, with future benefits expected as breeding and agronomic methods advance (Karim et al., 2024).

Risks of the invasive behaviour of Arundo donax

Arundo donax did not bloom even in the eighth year after planting, eliminating the risk of spread through generative reproduction. However, in the surrounding cultivated fields, intensive vegetative reproduction from underground organs was observed in the seventh year after planting (2022) (Figure 6). Under the controlled conditions of the field experiment, plants emerging in surrounding fields were removed during the growing season using mechanical methods (uprooting and mowing).

A total of 18 points was assessed, indicating a high risk of *Arundo donax* invasion under the studied conditions (Table 1). The species' significant plant height, high vegetative reproduction capacity, and density contribute to its invasive potential. Assessing the risk of invasive behaviour of *Arundo donax* requires further observations due to the intensity of vegetative reproduction by roots, which was observed in the seventh year after planting in 2022. Methods for assessing plant invasiveness have evolved rapidly over the past two decades. While many tools exist, none have been specifically designed to screen ornamental species before their introduction into the environment. Similarly, an assessment conducted in California showed that *Arundo donax* is not recommended for ornamental purposes due to its high invasive potential (Conser et al., 2015). *Arundo donax* is considered to be one of the worst invasive species in the world, and Jiménez-Ruiz et al. (2021) point out that it has been invasive in many countries of Europe, America, Africa and Oceania. It forms dense thickets along rivers, canals, and reservoirs. This prolific growth has significant consequences, as it removes water needed for agriculture and human consumption in areas with scarce rain-

Figure 6. Manifestations of the invasive behaviour of *Arundo donax* vegetative propagation

Table 1. Evaluation of the invasive potential of *Arundo donax*

Parameter/point value	0	1	2	3	4	5
Number of seeds per plant	×					
Ways of generative expansion	×					
Plant height						×
Vegetative reproduction						×
Plant density						×
Behaviour of the species in the country of origin				×		
Total invasion potential value			18			

0 point – was not recorded, 1 point represents the lowest score and 5 the highest score for a particular parameter

fall. Furthermore, its widespread presence transforms riparian ecosystems, promotes wildfires, outcompetes and displaces native plants and animals, and can facilitate the invasion of other species, thus having significant negative effects on biodiversity and ecosystem processes and also causing economic problems (Lambert et al., 2010; Abu-Romman and Ammari, 2015; Moran and Goolsby, 2022; Goolsby et al., 2023).

The research hypothesis was partially confirmed. The results of the long-term field study demonstrated that *Arundo donax* exhibits a high invasive potential despite the absence of viable generative reproduction, primarily due to its aggressive vegetative propagation and its ability to form dense, monospecific stands that suppress native vegetation. These characteristics significantly increase its capacity for persistence and spread beyond cultivation.

Risks of invasive behaviour of Paulownia clone R112 and hybrid 9501

The studied *Paulownia* plants flowered and produced seeds that did not germinate, indicating no risk of generative reproduction and, therefore, no immediate risk of invasion. However, future pollination by *Paulownia tomentosa* cannot be ruled out, nor can the possibility of producing viable seeds, which could increase the potential for their spread into the surrounding area. Both *Paulownia* plants exhibited intensive formation of root suckers and stem shoots (Figure 7). Under controlled conditions, the root suckers were mechanically removed during the growing season (uprooting, mowing, and sawing depending on their size).

Figure 7. Root suckers and stem shoots of *Paulownia* clone R 112

The potential invasion risk of *Paulownia* clone R112 was assessed with a score of 15, while hybrid 9501 scored 13 points (Table 2, 3). The most important factors contributing to their invasive potential include their intensive vegetative reproduction, height, and possible generative expansion via cross-pollination. Further monitoring is required to fully evaluate the invasive potential of these *Paulownia* clones at the studied site. Nasraoui et al. (2025) have confirmed that *Paulownia tomentosa* can vegetatively proliferate by root cuttings, which points out a high risk of spreading.

Although studies showed that *Paulownia* clone R112 have non-germinating seeds (Kadlec et al., 2021, 2023), since the clones can produce flowers, there is a hypothetical risk of cross-pollination with *Paulownia tomentosa*, which is cultivated in Slovakia as an ornamental tree in parks. The occurrence of *Paulownia tomentosa* has already been recorded in Bratislava (Danube ports), Piešťany, and forests adjacent to the Mlyňany Arboretum (Jankovič et al., 2016). In neighbouring Austria, its spread has been monitored, with findings published as early as 2007 (Essl, 2007). Therefore, the possibility that some seeds may germinate following pollination by *Paulownia tomentosa* cannot be ruled out, potentially facilitating the species' spread beyond the originally planted location, even if only a small percentage of seeds successfully germinate. Confirming or dismissing this risk requires long-term monitoring. Additionally, root propagation should be closely monitored, particularly when the root system is disturbed during mechanical weeding,

Table 2. Evaluation of the invasive potential of *Paulownia* clone R112

Parameter/point value	0	1	2	3	4	5
Number of seeds per plant	×					
Ways of generative expansion				×		
Plant height						×
Vegetative reproduction						×
Plant density		×				
Behaviour of the species in the country of origin	×					
Total invasion potential value			15			

0 point – was not recorded, 1 point represents the lowest score and 5 the highest score for a particular parameter

Table 3. Evaluation of the invasive potential of *Paulownia* hybrid 9501

Parameter/point value	0	1	2	3	4	5
Number of seeds per plant	×					
Ways of generative expansion				×		
Plant height						×
Vegetative reproduction				×		
Plant density		×				
Behaviour of the species in the country of origin	×					
Total invasion potential value			13			

0 point – was not recorded, 1 point represents the lowest score and 5 the highest score for a particular parameter

as all known clones exhibit a strong ability to reproduce vegetatively through root cuttings (Jankovič et al., 2016; Maľová et al., 2016).

The evaluated taxa of *Paulownia* (clone R112 and hybrid 9501) showed moderate invasive potential driven by vigorous vegetative reproduction through root suckers. However, during the monitoring period, no viable seed production was observed, which currently limits their dispersal capacity.

CONCLUSIONS

The global distributions of *Arundo donax* and *Paulownia* spp. show striking similarities, with the highest concentrations of recorded occurrences in Europe and North America. These patterns reflect extensive introduction and possible naturalization of both taxa outside their native ranges, particularly across temperate regions of Europe and North America.

The results of the nine-year study in western Slovakia indicate that *Arundo donax* poses a high risk of invasion, as it exhibits aggressive vegetative spread. Despite its inability to reproduce generatively in the studied conditions, its total invasion potential score of 18 confirms a strong capacity for vegetative expansion. This is particularly concerning given the species' ability to establish dense stands that may outcompete native vegetation and threaten biodiversity and ecosystems. Similarly, a ten-year assessment of fast-growing *Paulownia* clone R112 and hybrid 9501 suggests a possible risk of invasion. While neither the clone nor the hybrid exhibited generative reproduction, both demonstrated intensive vegetative propagation through root suckers, with invasion potential scores of 15 and 13, respectively. Potential hybridization with *Paulownia tomentosa* remains a concern, as it could lead to viable seed production and further spread. Given these findings, continuous monitoring and management of *Arundo donax* and *Paulownia* clones are essential to prevent their uncontrolled expansion. Further research is needed to evaluate long-term vegetative growth dynamics and potential interactions with native ecosystems.

Overall, while vegetative reproduction alone represents a substantial invasion mechanism, particularly in the case of *Arundo donax*, the absence of generative reproduction reduces, but does not eliminate, the risk of naturalization. The potential future hybridisation with *Paulownia tomentosa* may alter this risk and therefore requires continued monitoring.

ACKNOWLEDGEMENT

This publication was funded by the Grant Agency of the Slovak University of Agriculture (GA SPU), project No. 10-GA-SPU-2024 and by Slovakia's recovery and resilience plan, project No. 09I03-03-V05-00018 – Early Stage Grants at SUA in Nitra.

REFERENCES

Abu-Romman, S., Ammari, T. G. (2015) Allelopathic effect of *Arundo donax*, a Mediterranean invasive grass. Plant Omics Journal, 8, 287-291.

Act of the National Council of the Slovak Republic No. 150/2019 Coll. on the prevention and management of the introduction and spread of invasive alien species and on amendments to certain acts. Available at: https://www.slov-lex.sk/static/pdf/2019/150/ZZ_2019_150_20190801.pdf [Assessed 25 May 2025].

Antal, G. (2018) Giant reed (*Arundo donax* L.) from ornamental plant to dedicated bioenergy species: review of economic prospects of biomass production and utilization. International Journal of Horticultural Science, 24, 39-46. DOI: https://doi.org/10.31421/IJHS/24/1-2./1545

Badalamenti, E. (2019) Notes about the naturalization in Sicily of *Paulownia tomentosa* (*Paulowniaceae*) and remarks about its global spread. Flora Mediterranea, 29, 67-70. DOI: https://doi.org/10.7320/FlMedit29.067

Barančok, P., Kalivoda, H., Kostovský, D., Mutkovič, A., Varšavová, M. (1999) Local territorial system of ecological stability of the Hlohovec settlement unit. Bratislava, 105. (in Slovak)

CABI (2025a) *Arundo donax* (giant reed). Available at: https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.1940#toDistributionMaps [Accessed 06 June 2025]

CABI (2005b) *Paulownia tomentosa* (*Paulownia*) Available at: https://www.cabidigitallibrary.org/doi/full/10.1079/cabicompendium.39100 [Accessed 06 June 2025]

Commission Regulation (EU) No 2019/1262 amending Implementing Regulation (EU) 2016/1141 to update the list of invasive alien species of Union concern. Available at: https://eur-lex.europaeu/legal-content/SK/TXT/PDF/?uri=CELEX:32019R1262&from=FR [Accessed 06 May 2025]

Conser, C., Seebacher, L., Fujino, D. W., Reichard, S., DiTomaso, J. M. (2015) The development of a plant risk evaluation (PRE) tool for assessing the invasive potential of ornamental plants. Plos One, 10 (3). DOI: https://doi.org/10.1371/journal.pone.0121053

Decree No. 170/2021 Coll. implementing Act No. 543/2002 Coll. on Nature and Landscape Protection, as amended. Available at: https://www.zakonypreludi.sk/zz/2021-170 [Accessed 06 May 2025]

Demo, M., Húska, D., Jureková, Z., Miklós, N. (2013) Chinese ornamental grass (*Miscanthus sinensis*) as a source of biomass for energy purposes - cultivation purposes. Nitra: SUA, 43. (in Slovak)

Eliáš, P. (2023) Research on introduced plant species in Slovakia – from adventive floristics to invasive biology. Bulletin SBS, 45 (2), 229 (in Slovak). Available at: http://sbs.sav.sk/SBS1/bulletins/docs/bulletin45_2/BSBS-2023-2-Elias-st.pdf. [Accessed 06 May 2025]

EPPO (2021) *Paulownia tomentosa* in the EPPO region: addition to the EPPO Alert List (online). Available at: https://gd.eppo.int/reporting/article-7101 [Accessed 06 May 2025]

Essl, F. (2007) From ornamental to detrimental? The incipient invasion of Central Europe by *Paulownia tomentosa*. Preslia, 79, 377-389. Available at: https://www.presliacz/article/pdf?id=281 [Accessed 06 May 2025]

FOEN (2022) Alien Species in Switzerland. An inventory of alien species and their impact. Federal Office for the Environment, Bern. Environmental studies, 62.

GBIF (2025a) GBIF Occurrence Download. DOI: https://doi.org/10.15468/dl.4jputj.

GBIF (2025b) GBIF Occurrence Download. DOI: https://doi.org/10.15468/dl.kyxwzh

Ghazzawy, H., Bakr, A., Mansour, A., Ashour, M. (2024). *Paulownia* trees as a sustainable solution for CO2 mitigation: assessing progress toward 2050 climate goals. Frontiers in Environmental Science, 12. DOI: 10.3389/fenvs.2024.1307840.

Gojdičová, E., Cvachová, A., Karasová, E. (2002) List of non-native, invasive and expansive vascular plants of Slovakia 2. Ochrana prírody, 21, 59-79 (in Slovak). Available at: https://invaznedruhy.sopsr.sk/wp-content/uploads/2021/07/Zoznam-invaznych-rastlin.pdf. [Accessed 01 May 2025]

Goolsby, J. A., Moran, J. P., Jiménez, M. M., Yang, Ch., Canavan, K., Quentin Paynter, Q., Ota, N., Kriticos, D. J. (2023) Biology of Invasive Plants 4. *Arundo donax* L. Invasive Plant Science and Management, 16, 81-109. DOI: https://doi.org/10.1017/inp.2023.17

Government Regulation No. SR 449/2019 Coll., issuing a list of invasive alien species of concern to the Slovak Republic. Available at: https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2019/449/ [Accessed 01 May 2025]

Gubišová, M., Gubiš, J., Žofajová, A. (2016) Biomass production of gigantic grasses *Arundo donax* and *Miscanthus × giganteus* in the dependence on plant multiplication method. Agriculture, 62 (2), 43-51. DOI: https://doi.org/10.1515/agri-2016-0005

iNaturalist (2025a) Export Observations. Available at: https://www.inaturalist.org/observations/export?verifiable=true&page=1&spam=false&place_id=any&user_id=&project_id=&taxon_id=64017 [Accessed 06 June 2025]

iNaturalist (2025b) Export Observations. Available at: https://www.inaturalist.org/observations/export?verifiable=true&page=1&spam=false&place_id=any&user_id=&project_id=&taxon_id=119794 [Accessed 06 June 2025]

Jakubowski, M. (2022) Cultivation Potential and Uses of *Paulownia* Wood: A Review. Forests, 13 (5), 668. DOI: https://doi.org/10.3390/f13050668

Jakubowski, M., Tomczas, A., Jelonek, T., Grzywiński, W. (2018) Wood Use and Cultivation Possibilities of Trees of the *Paulownia* Genus. Acta Scientiarum Polonorum, 17, 291-297 (in Polish) DOI: https://doi.org/10.3390/f13050668

Jámbor, A., Török, Á. (2019) The Economics of *Arundo donax*—A Systematic Literature Review. Sustainability, 11, 4225. DOI: https://doi.org/10.3390/su11154225

Jankovič, J., Maľová, M., Longauerová, V., Sujová, K. (2016) Potential and risks of growing *Paulownia* clones in Slovakia. Current problems in forest establishment and cultivation. Zvolen: Národné lesnícke centrum, 96-108 (in Slovak). Available at: https://paulowniask/paulownia-odborny-clanok.pdf [Accessed 06 June 2025]

Jimenez-Ruiz, J., Hardion, L., Del Monte, J. P., Vila, B., Santin-Montanya, M. I. (2021) Monographs on invasive plants in Europe N degrees 4: *Arundo donax* L. Botany letters, 168 (1), 131-151. DOI: https://doi.org/10.1080/23818107.2020.1864470

Jureková, Z., Pauková, Ž., Bakay, L., Blehová, D., Zaujecová, A. (2019) Potential contribution of fast-growing *Paulownia* clones grown on arable land to the carbon cycle. Support for research activities at SUA in the field of energy. Nitra: SUA, pp. 68-76. (in Slovak)

Jureková, Z., Pauková, Ž., Húska, D., Giertl, T., Gaduš, J. (2022) Evaluation of properties and use hybrids of *Paulownia* grown in western Slovakia. Fast-growing trees and plants grown for energy purposes. Nitra: SUA, pp. 39-50. (in Slovak)

Kadlec, J., Novosadová, K., Pokorný, R. (2021) Preliminary results from a plantation of semi-arid hybrid of *Paulownia* Clone *in vitro* 112® under conditions of the Czech Republic from the first two years. Baltic Forestry, 27 (1), 477. DOI: https://doi.org/10.46490/BF477

Kadlec, J., Novosadová, K., Kománek, M., Pokorný, R. (2023) Testing the Production Potential of *Paulownia* Clon *In Vitro* 112® in the Czech Republic. Forests, 14, 1526. DOI: https://doi.org/10.3390/f14081526

Kadlec, J., Novosadová, K., Pokorný, R. (2024a) Evaluation of the growth of one species and two hybrids of *Paulownia* spp. in the warmest region of South Moravia. Zprávy lesníckeho výskumu, 3, 188-196 (in Czech). DOI: https://doi.org/10.59269/ZLV/2024/3/734

Kadlec, J., Novosadová, K., Palovčíková, D., Tomšovský, M., Kománek, M., Pokorný R. (2024b) First Experience of *Paulownia* Bellissia® Cultivation in an Agroforestry System in the Czech Republic. Lesnoy Zhurnal, 3, 9-22 (In Russ.). DOI: https://doi.org/10.37482/0536-1036-2024-3-9-22

Kassem, H. M., Ali, H. E., Zaghloul, M. S. (2024) *Arundo donax* L. in Egypt: a potentially valuable economic plant. Advances in Basic and Applied Sciences. DOI: https://doi.org/10.21608/abas.2024.268352.1041

Karim, A., Ali, A., Qazi, B. A., Zarif, N., Shah, W. (2024) Significance of Cultivating Genus *Paulownia* and its Utilization in Different Sectors: A Review. Pakistan Journal of Forestry, 74 (2), 70-78. DOI: https://dx.doi.org/10.17582/journal.PJF/2024/74.2.70.78

Lambert, A. M., Dudley, T. L., Saltonstall, K. (2010) Ecology and Impacts of the Large-Statured Invasive Grasses *Arundo donax* and *Phragmites australis* in North America. Invasive Plant Science and Management, 3 (4), 489-494. DOI: https://doi.org/10.1614/IPSM-D-10-00031.1

Lugli, L., Mezzalira, G., Lambardi, M., Zhang, H., La Porta, N. (2023) *Paulownia* spp.: A Bibliometric TrendAnalysis of a Global Multi-Use Tree. Horticulturae, 9, 1352. DOI: https://doi.org/10.3390/horticulturae9121352

Maľová, M., Jankovič, J., Sujová, K., Longauerová, V., Mútňáková, M. (2016) *Paulownia* - Potential and risks of cultivation in Slovakia. Proceedings of the Conference: Current Issues in Forest Protection, 87-95 (in Slovak). Available at: https://www.los.sk/pdf/apol_zbor16.pdf

Mártonfi, P. (1997) *Paulownia* Siebold et Zucc. Paulovnia. In: Goliašová, K., ed. Flora of Slovakia V/2. Bratislava: Veda, pp. 25-26.

Medvecká, J., Kliment, J., Májeková, J., Halada, Ľ., Zaliberová, M., Gojdičová, E., Feráková, V., Jarolímek, I. (2012) Inventory of the alien flora of Slovakia. Preslia, 84, 257-309. Available at: https://www.presliacz/P122Medvecka.pdf [Accessed 06 June 2025]

Mooschová, J. (2006) Assessment of the invasive potential of introduced plant species. Doctoral dissertation (PhD.). Nitra: SUA, 182. (in Slovak)

Moran, P. J. & Goolsby, J. A. (2022) Biological control of *Arundo*, an invasive grass threatening water resources and national security. In: Van Driesche, R. G., Winston, R. L., Perring, T. M. and Lopez, V. M. eds. Contributions of Classical Biological Control to the U.S. Food Security, Forestry, and Biodiversity. USDA Forest Service, Morgantown, West Virginia, USA, pp. 373-389. Available at: https://bugwoodcloud.org/resource/files/23194.pdf

Nasraoui, A. H., Heikal, Y. M., Ali, M., Abidi, C., Ammari, Y. (2025) Regenerative Capacity of *P. tomentosa* Steud. Through Different Root Cuttings Explants Diameters Derived from Selected Mature Trees, Growth Hormone Dose and Soil Type. Preprints. DOI: https://doi.org/10.20944/preprints202505.0197.v1

Negrușier, C., Buzan, L. R., Păcurar, I., Sîngeorzan, S. M., Ceuca, V., Colișar, A., Andreica, I., Rózsa, S., Borsai, O. (2025) Economic Sustainability Assessment of *Paulownia* Farms in a Dual Production System—Case Studies in Temperate Climates. Sustainability 17, 21. DOI: https://doi.org/10.3390/su17010021

Pauková, Ž. (2021) Biotic invasions. Praha: Verbum, 145. (in Slovak)

Pauková, Ž., Jureková, Z. (2017) Seedlings growth and biomass production of *Arundo donax* cultivated in southwest Slovakia. Fast-growing trees and plants growing for energy purposes. Nitra: SUA. (in Slovak)

Pauková, Ž., Jureková, Z. (2018) Diversity of stomata of two taxa perennial bioenergy grasses. Influence of abiotic and biotic stressors on plant properties. Praha: CZU. pp. 173-177. (in Slovak)

Pauková, Ž., Jureková, Z. (2019) Vertical distribution of aboveground biomass of energy grass *Arundo donax* in second year after planting. Fast-growing trees and plants grown for energy purposes. Nitra: SUA (in Slovak)

Pauková, Ž., Prčík, M., Wójcik-Gront, E. (2022) Biomass production and growth dynamics of the energy grass *Arundo donax*. Praha: Verbum, 87. (in Slovak)

Pástor, M., Jankovič, J., Belko, M., Modranský, J. (2022) Evaluation of selected growth parameters of *Paulownia cotevisa* plantation in Danubian Lowland. Journal of Forest Science, 68, 156-162. DOI: https://doi.org/10.17221/155/2021-JFS [Accessed 06 June 2025]

Pergl, J., Sádlo, J., Petrusek, A., Laštůvka, Z., Musil, J., Perglová, I., Šanda, R., Šefrová, H., Šíma, J., Vohralík, V., Pyšek, P. (2016) Black, Grey and Watch Lists of alien species in the Czech Republic based on environmental impacts and management strategy. NeoBiota, 28, 1-37. DOI: https://doi.org/10.3897/neobiota28.4824

Pyšek, P., Danihelka, J., Sádlo, J., Chrtek, J. Jr., Chytrý, M., Jarošík, V., Kaplan, Z., Krahulec, F., Moravcová, L., Pergl, J., Štajerová, K., Tichý, L. (2012) Catalogue of alien plants of the Czech Republic (2nd edition): checklist update, taxonomic diversity and invasion patterns. Preslia, 84, 155-255. Available at: https://biblio.cbnpmp.fr/index.php?lvl=notice_display&id=135312 [Accessed 06 June 2025]

Pyšek, P., Sádlo, J., Chrtek, J. Jr., Chytrý, M., Kaplan, Z., Pergl, J., Pokorná, A., Axmanová, I., Čuda, J., Doležal, J., Dřevojan, P., Hejda, M., Kočár, P., Kortz, A., Lososová, Z., Lustyk, P., Skálová, H., Štajerová, K., Večera, M., Vítková, M., Wild, J., Danihelka, J. (2022) Catalogue of alien plants of the Czech Republic (3nd edition): species richness, status, distributions, habitats, regional invasion levels, introduction pathways and impacts. Preslia, 94, 447-577. DOI: https://doi.org/10.23855/preslia2022.447

Pyšek, P., Sádlo, J., Mandák, B. (2002) Catalogue of alien plants of the Czech Republic. Preslia, 74, 97-186. DOI: https://doi.org/10.23855/preslia2022.447

Richardson, D. M., Pyšek, P., Rejmánek, M., Barbour, M. G., Panetta, F. D., West, C. J. (2000) Naturalization and invasion of alien plants: concepts and definition. Diversity and Distribution, 6, 93-107. DOI: https://doi.org/10.1046/j.1472-4642.2000.00083.x

Sławińska, N., Zając, J., Olas, B. (2023) *Paulownia* Organs as Interesting New Sources of Bioactive Compounds. International Journal of Molecular Sciences, 24 (2), 1676. DOI: https://doi.org/10.3390/ijms24021676

SHMÚ SR (2025). Climatic condition SR. (in Slovak). Available at: https://www.shmu.sk/sk/?page=1064 [Accessed 06 June 2025]

Snow, W. A. (2015) Ornamental, crop, or invasive? The history of the Empress tree (*Paulownia*) in the USA. Forests, Trees and Livelihoods, 24, 85-96. DOI: https://doi.org/10.1080/14728028.2014.952353

ŠOP SR (2024) Invasive species. (in Slovak). Available at: https://invaznedruhy.sopsr.sk/ [Accessed 06 January 2025]

Velez-Gavilan, J. (2024) *Arundo donax* (giant reed). Available at: https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.1940#toDistributionMaps [Accessed 06 January 2025]

Williams, C. E. (1983) The exotic empress tree, *Paulownia tomentosa*: an invasive pest of forests. Natural Areas Journal, 13, 221-222.

Williams, R., Wang, H. (2021) Effects of Wildfire and the Presence of the Invasive *Paulownia tomentosa* on the Regeneration of Native Tree Species in North-Central Appalachia. Fire, 4 (3), 60. DOI: https://doi.org/10.3390/fire4030060

Yadav, N., Vaidya, B., Henderson, K., Lee, J., Stewart, W., Dhekney, S., Joshee, N. (2013) A Review of *Paulownia* Biotechnology: A Short Rotation, Fast Growing Multipurpose Bioenergy Tree. American Journal of Plant Sciences, 4 (11), 2070-2082. DOI: https://doi.org/10.4236/ajps.2013.411259