



OPEN Early warning of two emerging plant invaders in Europe

Aneta Bylak^{1✉}, Andrzej Bobiec², Mateusz Bobiec², Krzysztof Kukuła¹ & Tim Low³

The pool of invasive ornamental plants keeps expanding, and one of the best studied plant invasion habitats is the riparian zone. Europe has no native *Miscanthus* spp. or bamboos, which are popular garden plants. In 2022–2024 we observed Bisset bamboo (*Phyllostachys bissetii*) and giant miscanthus (*Miscanthus × giganteus*) naturalizing in the riparian zones of two rivers of the Vistula River basin (Poland). Bisset bamboo has not been recorded before in the wild in Europe and giant miscanthus has not been reported before as naturalized in Europe. We describe their present habitats and invasive potential, to alert others to the prospect of spread in Europe. Examples from other parts of world indicate that *Phyllostachys* spp. invasive running bamboo has a tendency to spread aggressively. Because we only located single plants our species qualify as ‘casuals’, but we mention them out of a concern that these species are establishing more widely or will soon do so. Our observations fit an “accelerated trend” in exotic plant invasion in Europe, in particular, of escaped ornamental plants. Based on information about the ecology of both species, their popularity in horticulture, and our observations, we speculate that giant miscanthus and Bisset bamboo may become new European plant invaders. Both species should be mechanically removed. There is an urgent need to raise awareness among gardeners, hobbyists, plant sellers and importers, about environmental risk from spread of invasive plants. It is concerning that seedlings and seeds of other species of the genera *Miscanthus* and *Phyllostachys*, which have naturalised in several European countries, are available in horticulture. Bioinvasion is easier to control if there is early detection and a rapid response.

Keywords Invasion corridor, *Phyllostachys bissetii*, *Miscanthus × giganteus*, Running bamboo, Ecosystem protection, River basins

Reducing the rate of introduction and establishment of invasive or potentially invasive alien species is one of the targets of the Kunming-Montreal Global Biodiversity Framework 2030¹. Unfortunately, the pool of invasive ornamental plants keeps expanding². In Europe, many of them are tall-statured grasses (defined as grass species that maintain a self-supporting height of 2 m or greater³) e.g., exotic *Miscanthus* grasses, or such belonging to the *Bambusoidae* family⁴. Europe has no native *Miscanthus* or bamboos⁵. The latter were first imported into Europe several hundred years ago⁶, and the former have been grown since the 1930s⁷. Some of these plants are invasive elsewhere, especially the so-called running bamboos, including *Phyllostachys* species^{8–13}. Due to fast growth and adaptation to a cool climate, the hybrid giant miscanthus (*Miscanthus × giganteus*) has escaped in the USA¹⁴, and elsewhere.

In 2022–2024 we observed Bisset bamboo (*Phyllostachys bissetii*) and giant miscanthus as naturalized plants. Each has, established in the ecotonal zones of two Central European rivers of the Carpathian Vistula River basin (Poland). One species is new for Europe and one is new for southeastern Poland. Neither species has been recognized in Europe as invasive so far. Bisset bamboo does not appear on the checklists of alien plants of Europe and Poland^{15–18}, and is a new alien species for Europe. Alien giant miscanthus also does not appear on these lists^{15–18} and only in the Global Naturalized Alien Flora (GloNAF) database owing to one site in Germany¹⁹. The Global Biodiversity Information Facility (GBIF) dataset for Europe includes occurrences of *M. giganteus* (record: *Miscanthus giganteus* J.M.Greef & Deuter) and *M. xgiganteus* = *M. × longiberbis* (record: *Miscanthus × giganteus* JMGreef & Deuter ex Hodk. & = *Miscanthus × longiberbis* (Hack.) Nakai), in Germany, Austria, France, Switzerland, Sweden, the Netherlands, and one in Great Britain and one in Poland²⁰ (Table S1). Our aim was to describe the present habitats and invasive potential of *M. giganteus* and *P. bissetii*, to alert others to the prospect of their wider spread in Europe. Other species of the genera *Phyllostachys* and *Miscanthus* have already been included in the Global Register of Introduced and Invasive Species checklists for several European countries^{18,21–31} (Fig. 1, Table S2). The occurrence of some of them was also recorded in the GBIF²⁰ dataset for

¹Department of Ecology and Environmental Protection, University of Rzeszów, Rzeszów, Poland. ²Department of Nature Conservation and Landscape Ecology, University of Rzeszów, Rzeszów, Poland. ³Invasive Species Council, Katoomba, Australia. ✉email: abyalak@ur.edu.pl

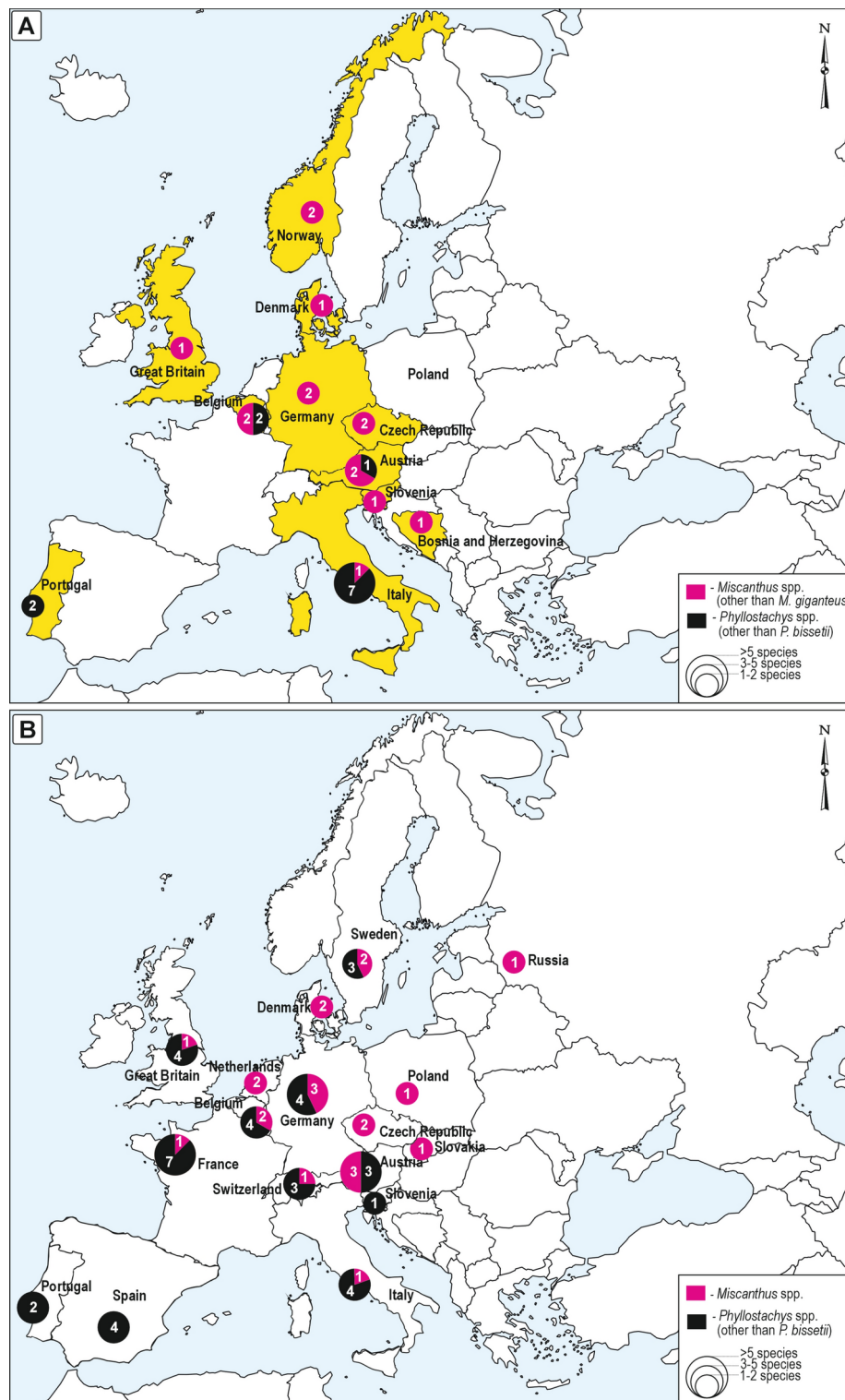


Fig. 1. European countries a) whose lists of alien and invasive species (according to the GRIS¹⁸ national lists see also Table S2) include species of the genera *Miscanthus* and/or *Phyllostachys* were marked in yellow, and b) where (according to the GBIF¹, see also Table S3) species of the genera *Miscanthus* and/or *Phyllostachys* have been found outside botanical gardens and palm houses (CorelDRAW v. 21.0, ArcMap v.10.7.1).

Europe, in areas outside botanical gardens (Fig. 1, Table S3). It cannot be ruled out that *Phyllostachys bisetii* is more widely distributed in Europe, but e.g., could only be identified in the genus due to difficulties in species identification. Therefore, there is an urgent need for formal publications that confirm the identify that will help to organize the data and more fully assess the potential invasiveness of *Phyllostachys* spp. bamboos in Europe.

Results and discussion

Giant miscanthus and Bisset bamboo were found in the San River basin (a right-bank tributary of the Vistula River; southeastern Poland) (Fig. 2, Table S4). Miscanthus was detected in the riparian zone of the Magierka Stream (tributary of the San river) in August 2023. It was a one patch of grass with six stems about 3.5 m high (Fig. 3). By July 2024 it had increased to 12 stems (Fig. 3). A strip of trees and bushes has been preserved along the stream, and a little further on there was sparse rural development. The location is in the East Beskid Area of Protected Landscape, and the San River (the recipient of the Magierka Stream) is included in the Natura 2000 network of protected areas (i.e., with the Habitats Directive³²). Bisset bamboo was discovered in February 2022 on the Lubatówka River (the Wisłok River's tributary—the largest river feeding the San River; Fig. 4). The Wisłok River (the recipient of the Lubatówka River), is included in the Natura 2000 network of protected areas³². The bamboo had formed a circular stand of about four square metres, which after two years had expanded into a thicket 18-m long and 1.5–4-m wide, occupying ca. 50 m². Despite our efforts, we could not determine the source of these plants. They were not growing in any nearby home gardens. We suspect they originated in gardens upstream and were transported after bank erosion.

The giant miscanthus, a hybrid of Chinese silver grass (*M. sinensis*) and Amur silver grass (*M. sacchariflorus*), originates from South-East Asia. It is characterised by fast growth and dense tufts^{14,33}. In Poland it has recently become a very popular ornamental plant (see Fig. 3). Expansion of the patch in the riparian zone of the Magierka Stream indicated the plant could tolerate winter frost and snow cover (Fig. 3). As a sterile hybrid, *M. × giganteus* flowers in autumn (in Poland) but does not produce seeds. It can spread widely in riparian areas if floods erode banks and transport fragments of its rhizomes³³. The steep slope of the Magierka Stream favours bank erosion. The potential for downstream spread of rhizomes with water seems high. In the Magierka Stream riparian zone, native plants include black elderberry *Sambucus nigra*, dogwood *Cornus sanguinea*, and among herbaceous plants—native grass species and hedge bindweed *Calystegia sepium*. Miscanthus as a perennial grass with bamboo-like stems clearly taller than native grasses. Plant height is a key trait³⁴. Increased height helps with initial colonisation, assisting with light capture and competitive ability³⁵. Invasive tall-statured grasses are noted for their ability to dominate plant communities and alter ecosystem functioning^{3,36,37}.

Bisset bamboo may pose a far more serious risk. There are no bamboos native to Europe and they have not been popular in cultivation, in part because most horticultural species cannot tolerate the winter temperatures.

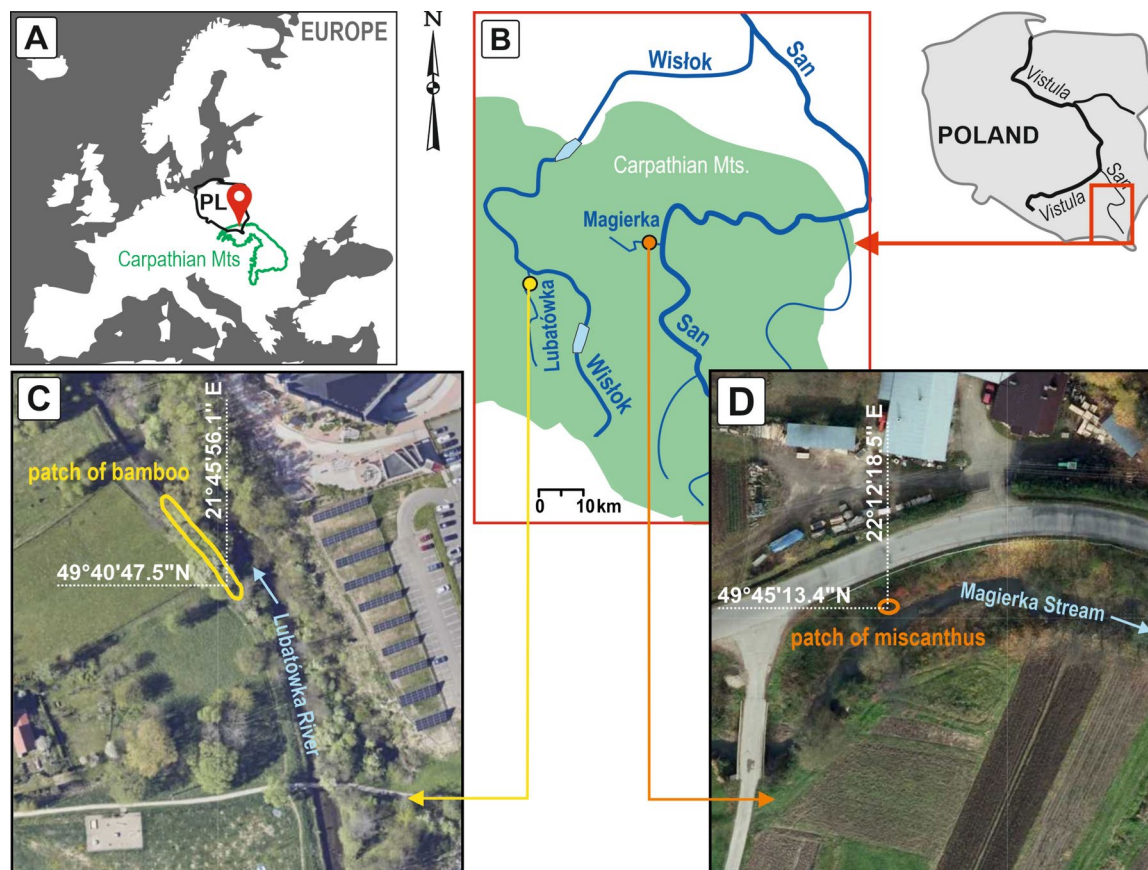


Fig. 2. Map of the study area; location against the background of Europe (a) and Poland (b); orthophotomaps (c, d) of a fragment of the catchment area of the Magierka Stream (c) and the Lubatówka River (d). (CorelDRAW v. 21.0, ArcMap v.10.7.1, <https://mapy.geoportal.gov.pl/wss/service/PZGIK/NMT/GRID1/WMT> S).

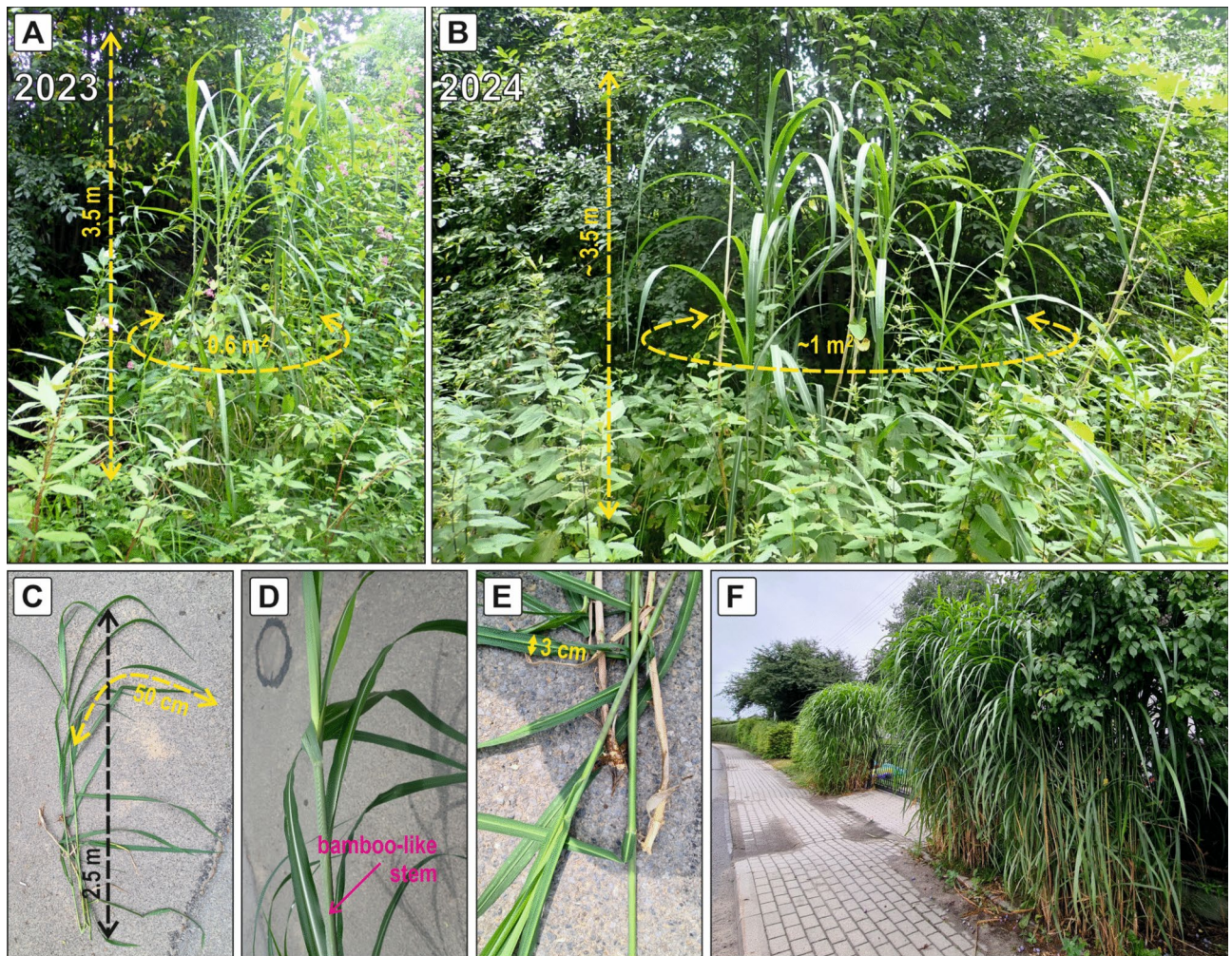


Fig. 3. *Miscanthus x giganteus* in the Magierka Stream riparian zone (**a**, **b**), characteristic features of the plant (**c**–**e**), and an example of cultivation in southeastern Poland (**f**) (July 1, 2024).

However, increasing interest in bamboos has encouraged gardeners and the horticulture industry to import species tolerant of frost and snow cover³⁸. Ten species can now be bought from nurseries in Poland (Table 1). Several species from temperate Asia, including aggressively spreading *Phyllostachys* species¹⁰, have naturalised in other part of world^{11,12}. Temperate bamboos have a long history in European horticulture⁵, but only limited naturalization has been reported so far. In Europe, Italy has reported the largest number of naturalized *Phyllostachys* species (seven)¹⁸ (Table S2). However, bamboos are becoming more popular in horticulture, perhaps due to the return of the “bamboo fad” bringing a touch of overseas to the garden, maybe due to more affordable prices or easier online sales (Table 1). *Phyllostachys* bamboos can spread indefinitely via rhizomes⁴, and gardeners are advised to install root barriers when growing them¹⁰. The riparian zone of the Lubatówka River lacks natural barriers, such as rocky reefs, boulders or ditches, so further vegetative spread can be expected, along with dispersal of rhizomes during floods.

One of the best studied plant invasion corridors are river valleys, and especially their riparian zones^{39,40}. The riparian zone of the San River (Fig. S1) has numerous invasive alien species that were originally grown for ornamental or other purposes. These include Himalayan balsam *Impatiens glandulifera*, woodland sunflower *Helianthus tuberosus*, coneflower *Rudbeckia laciniata*, Japanese knotweed *Reynoutria japonica*, and vines such as balsam-apple *Echinocystis lobata* and Virginia creeper *Parthenocissus quinquefolia* (Fig. 5). Because we only located single plants, giant miscanthus and Bisset bamboo qualify as ‘casuals’ rather than as naturalised or invasive⁴¹, but we mention them out of a concern that these species are establishing more widely or will soon do so.

Currently, in the Lubatówka River riparian zone, native plants include willows *Salix* spp., hazel *Corylus avellana*, bird cherry *Padus avium*, black elderberry *Sambucus nigra*, guelder rose *Viburnum opulus*, and dogwood *Cornus sanguinea* (Table S5). Bisset bamboo has shown it can compete with these by forming a large, compact stand with a high density of stems. Species in genus *Phyllostachys* are “runners”, i.e., they send underground rhizomes to produce shoots several meters from parent plants. This growth form enables them to spread more rapidly than other bamboo species⁴². With vegetative growth, bamboos can outcompete native

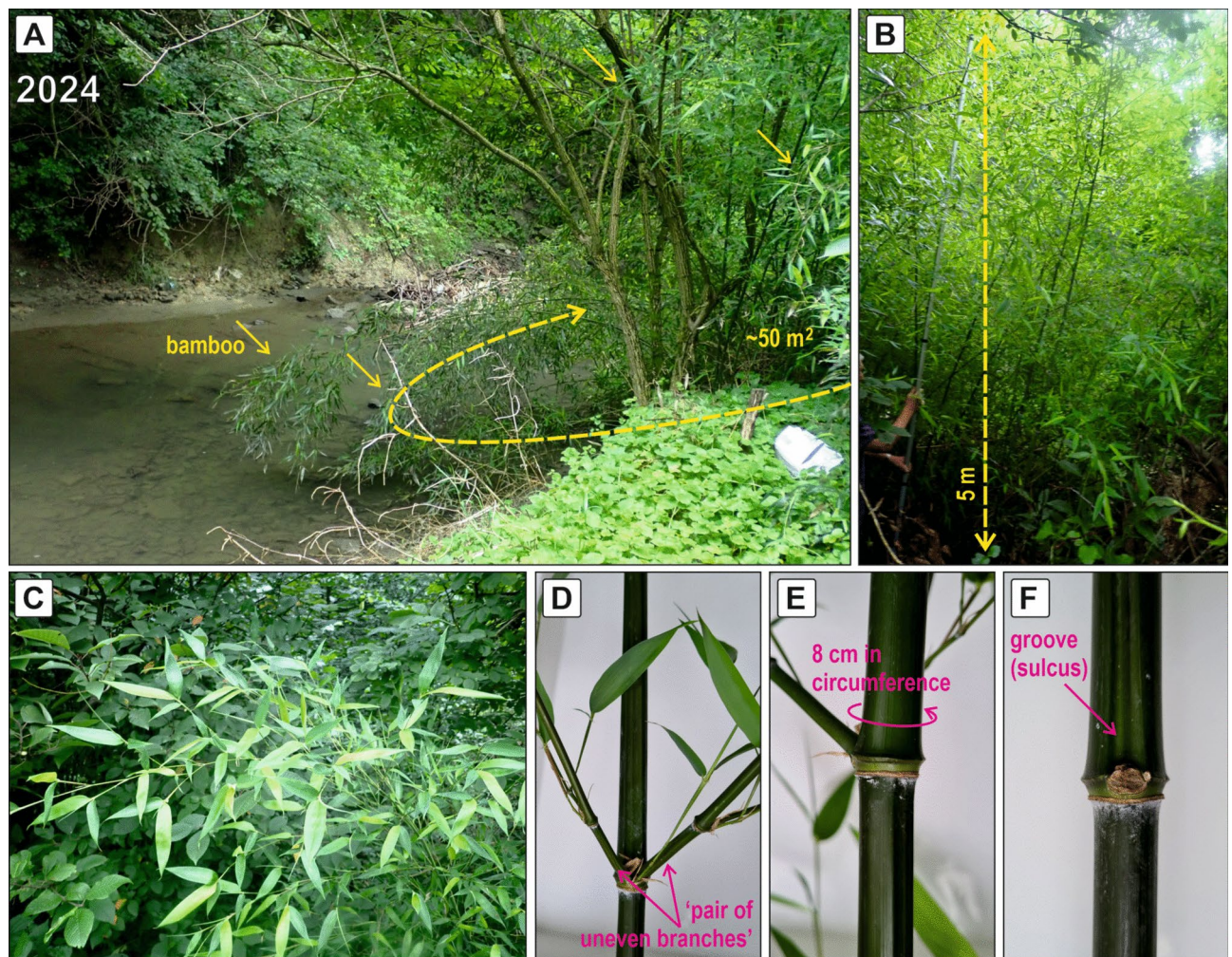


Fig. 4. *Phyllostachys bissetii* in the riparian zone of Lubatówka River (a–c) and characteristic features of the plant (d–f); (July 19, 2024).

shrubs and saplings of native trees, establishing “monocultural” thickets⁴³. Invasive bamboos may suppress understory plants^{3,10,44,45}. *Phyllostachys nigra* and *P. pubescens* in Puerto Rico have transformed biologically rich coastal forests into bamboo monocultures⁴⁶. Suzaki and Nakatsubo⁴⁷ documented the decrease of the understory and perennial plant richness caused by the increasing density of *P. bambusoides* stems, and bamboos can displace animals^{12,48}, and disrupt hydrology and surface runoff, and deplete soil nutrients¹¹. In forests affected by spreading running bamboo species (*Phyllostachys pubescens* and *P. bambusoides*) in western Japan, adverse changes in soil silica content were observed⁴⁹. The expansion of *P. edulis* simplified the community composition and structure of the secondary evergreen broad-leaved forest and reduced species diversity⁵⁰. Three of the biological traits contributing to this invasiveness include an ability to: (i) invade a neighbouring broadleaved forest by vigorous rhizomes; (ii) compete successfully for soil nutrients; and (iii) tolerate strong wind and heavy snow accumulation^{38,51}.

Non-native invasive plants have increasingly become a major threat to natural areas by displacing native species and wildlife and significantly degrading habitats. Today, they are considered one of the greatest threats to natural areas and global biodiversity^{52,53}. Bamboo has the potential to transform the functioning of the whole aquatic ecosystem, beginning with the shredder functional group (among benthic macroinvertebrates). Dense tall bamboo thickets can produce more litter than native riverine plant communities, and the rate of decomposition of bamboo leaves in the river may be slower⁴⁶, resulting in changes in the rate and quality of coarse organic matter flowing into the stream and structure of the macrozoobenthos, i.e. a main link between basal resources and upper trophic levels in the river food web such as fishes^{54,55}. Examples from the other part of world indicate that, the *Phyllostachys* invasive running bamboo has a tendency to spread aggressively⁹.

Conclusion

Until recently, in the region where we discovered these species (Fig. 2), the climatic conditions for plants sensitive to low temperatures were described as moderate or even difficult⁵⁶. Discovery of these two species is concerning, and should draw attention to the possibility of further escapes of these and other garden plants, especially species

Category—common name	Common name	Scientific name	Inclusion on the lists of introduced and invasive species in European countries ¹⁸
Clumping bamboo	Narrow-leaved bamboo	<i>Fargesia angustissima</i>	None
	Fountain bamboo	<i>Fargesia nitida</i>	None
	Umbrella bamboo	<i>Fargesia robusta</i>	None
	Dragon head bamboo	<i>Fargesia rufa</i>	None
	Dwarf white stripe bamboo	<i>Pleoblastus variegatus</i>	None
	Pigmy bamboo	<i>Pleoblastus distichus</i>	Belgium
	Chinese fountain-bamboo*	<i>Fargesia spathacea</i> *	Belgium, Great Britain
Running bamboo	Golden bamboo	<i>Phyllostachys aurea</i>	Italy, Portugal
	Yellow-groove bamboo	<i>Phyllostachys aureosulcata</i>	None
	Bisset bamboo	<i>Phyllostachys bissetii</i>	None
	Black bamboo	<i>Phyllostachys nigra</i>	Austria, Italy, Portugal
	Moso bamboo	<i>Phyllostachys pubescens</i>	Italy
	Giant timber bamboo*	<i>Phyllostachys reticulata</i> (<i>P. bambusoides</i>)*	Italy
	Green glaucous bamboo*	<i>Phyllostachys viridiglaucescens</i> *	Italy, Belgium
	Red-margined bamboo*	<i>Phyllostachys violascens</i> *	Italy
	Sulphur bamboo*	<i>Phyllostachys sulphurea</i> *	Italy
Elephant grass	Giant miscanthus	<i>Miscanthus giganteus</i>	None
	Chinese silver grass	<i>Miscanthus sinensis</i>	Austria, Belgium, Bosnia and Herzegovina, Czech Republic, Denmark, Germany, Great Britain, Norway, Slovenia, Italy
	Amur silver grass	<i>Miscanthus sacchariflorus</i>	Austria, Belgium, Czech Republic, Germany, Norway

Table 1. Species of ornamental grasses (Poaceae) from the *Miscanthus* genus and the bamboo family (Bambusoideae), the seedlings or seeds (marked with an asterisk) of which could be purchased in garden centres in south-eastern Poland in 2022–2024;

from the genera *Miscanthus* and *Phyllostachys*. Bioinvasion is easier to control if there is early detection and a rapid response.

Our observations of giant miscanthus and Bisset bamboo fits an “accelerated trend” in exotic plant invasion in Europe, in particular, of species propagated as ornamental plants. Both species survived the difficult winter time. As each of them is clonal, there is a high probability of their further expansion through rhizomes (Fig. 6). Based on information about the ecology of both species, their popularity in horticulture, and our observations, we speculate that miscanthus and Bisset bamboo may become widespread European plant invaders.

To prevent negative impacts (e.g.^{44,46,47}), both species should be removed from the sites they have colonized. Due to the proximity of the rivers, herbicides should not be used. We suggest mechanical removal of running bamboo and miscanthus.

There is an urgent need to raise awareness among gardeners, hobbyists, plant sellers and importers, about ecological and environmental risks from spread of invasive alien plants. It is concerning that seedlings and/or seeds of *M. giganteus*, *P. bissetii* and other species from the genera *Miscanthus* and *Phyllostachys*, which have been listed as introduced in several European countries, are available in the Polish garden market, including online sites (Table 1, Table S2).

Materials and methods
Ethics statement

A sampling permit for fish studies and riparian zone assessment (No. RG-IV.7143.6.2022.MP) was issued by the Marshal Office of the Podkarpackie Voivodeship following approval by the Regional Directorate for Environmental Protection. In Poland no additional permit is required for sampling alien and exotic plants.

Study area
Sampling sites

Monitoring studies of fish communities in the middle and upper San River and its tributaries were conducted in 2022–2024. At the 65 sampling sites (Fig. S1), i.e., 150–250 segments of rivers and streams, the main characteristics of the riparian zone were described. Attention was also paid to the presence of invasive alien plants in the riparian zone (according to the River Habitat Survey (RHS) method).

Bamboo and miscanthus sites

The bamboo site was located on the banks of the Lubatówka River in the town of Krosno (southeastern Poland) at an altitude of 264 m above sea level. Lubatówka River (length 29 km, catchment area 89 km²) is a left-bank tributary of the Wisłok River (left tributary of the San River, 228 km, Vistula River basin). In turn, the miscanthus site was located in the riparian zone of the Magierka Stream, at an altitude of 258 m above sea level. The Magierka Stream is a left-side tributary of the San River. The Magierka Stream is 20 km long and has a catchment area of 41 km².

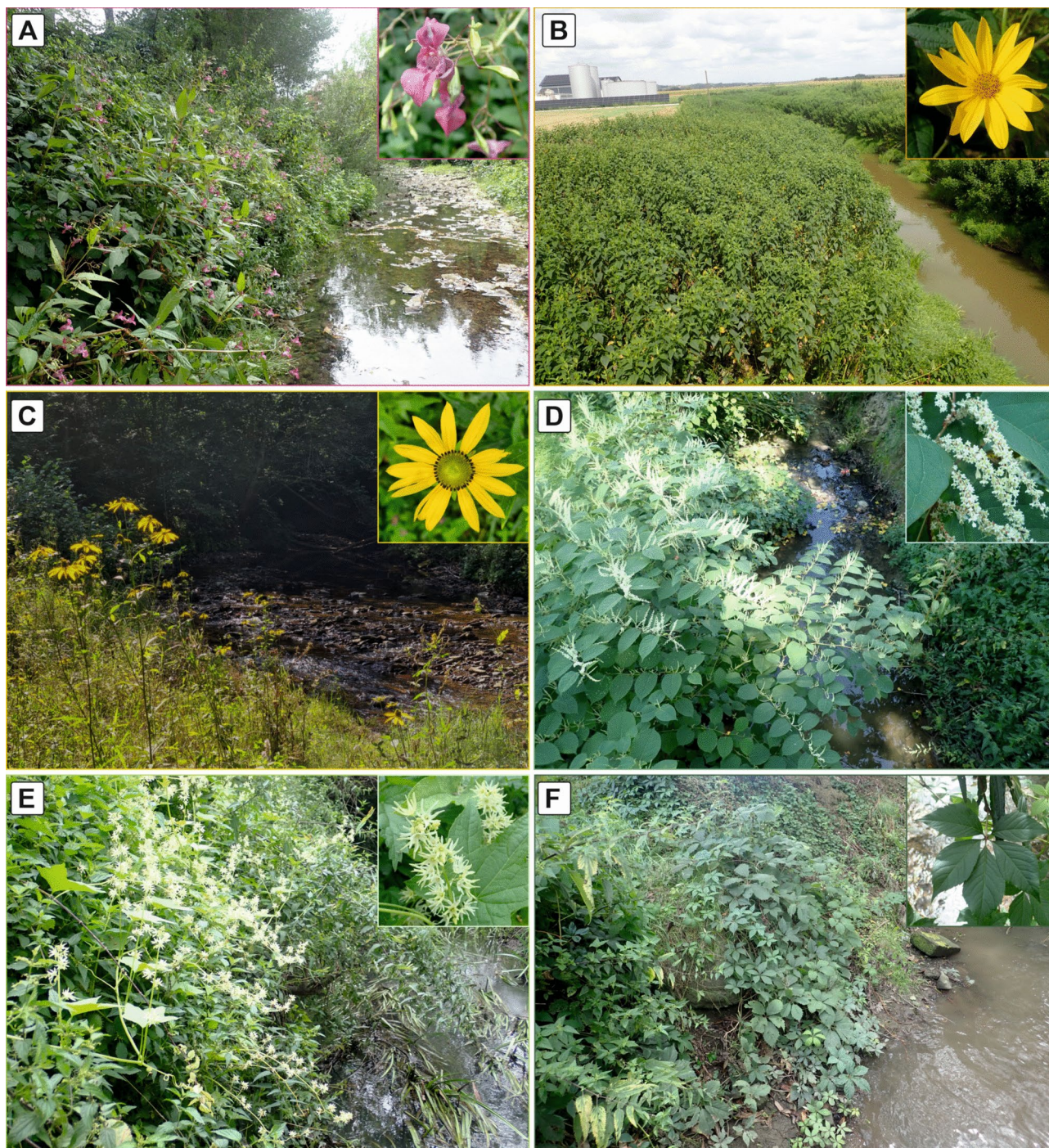


Fig. 5. Invasive alien species that were originally introduced e.g., for ornamental purposes, noted in the riparian zone of the San River catchment (A) Himalayan balsam *Impatiens glandulifera*, (B) woodland sunflower *Helianthus tuberosus*, (C) coneflower *Rudbeckia laciniata*, (D) Japanese knotweed *Reynoutria japonica*, (E) balsam-apple *Echinocystis lobata*, (F) Virginia creeper *Parthenocissus quinquefolia*.

Both research sites are located in the Carpathians in the Central Beskid Foothills mesoregion. The highest elevations of this area are approximately 600 m above sea level. The area belongs to the temperate climate and submontane climate zone, with features of a transitional climate. The average annual temperature for the multi-year period (1991–2020 Normals) is + 18 °C in July and around – 3 °C in January. There are around 40 days per year with an average air temperature below 0 °C. The average annual precipitation is around 750 mm to 800 mm. In the last two years (2022 and 2023), the average monthly air temperatures were higher than the multi-year averages, i.e. for January they were – 0.8 °C and 2.5 °C, respectively, and for July 19.2 °C and 19.6 °C, respectively.



Fig. 6. Bisset bamboos (A) pulled from soil from the riparian zone of the Lubatówka River, showing how the rhizome spreads and sprouts new culms and roots along its length as it grows (September, 2024); and (B) in winter (January, 2025).

Data availability

All data are included in the article and its supplementary information files.

Received: 20 January 2025; Accepted: 21 March 2025

Published online: 05 April 2025

References

1. CBD. Convention on Biological Diversity. *Decision adopted by the conference of the parties to the convention on biological diversity 15/4*. Kunming-Montreal global biodiversity framework CBD/COP/DEC/14/8. <https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-en.pdf> (2022).
2. Arianoutsou, M. et al. Alien plants of Europe: Introduction pathways, gateways and time trends. *PeerJ* **1**:9, e11270 (2021).
3. Canavan, S. et al. Tall-statured grasses: A useful functional group for invasion science. *Biol. Invasions* **21**, 37–58 (2019).
4. Canavan, S. et al. The global distribution of bamboos: Assessing correlates of introduction and invasion. *AoB PLANTS* **9**, plw078 (2017).
5. Liese, W. & Hamburg, F. R. G. Research on Bamboo. *Wood Sci Technol.* **21**, 189–209 (1987).
6. Crompton, D. Ornamental bamboos. Timber Press (Portland, Oregon), 1–306 (2006).
7. Schwarz, H., Liebhard, P., Ehrendorfer, K. & Ruckebauer, P. The effect of fertilization on yield and quality of *Miscanthus sinensis* ‘Giganteus’. *Ind. Crops Prod.* **2**, 153–159 (1994).

8. Rickel, C. Field guide to identification of *Phyllostachys* invasive running bamboo. Institute of Invasive Bamboo Research: 1–34 (2013).
9. Rickel, C. S. B. 72 An act concerning liability for growing of running bamboo. <https://www.cga.ct.gov/2014/envdata/tmy/2014SB-00072-R000219-MS.%20Caryn%20Rickel%20CPCU.%20Institute%20of%20Invasive%20Bamboo%20Research-TMY.PDF> (2014).
10. Pagad, S. Bamboos and invasiveness. Identifying which bamboo species pose a risk to natural environments, and what can be done to reduce this risk. IUCN SSC Invasive Species Specialist Group, INBAR - International Network for Bamboo and Rattan Working paper 77 (Beijing, P.R. China), 1–40 (2016).
11. Smith, M. C. & Mack, R. N. Shade tolerance of temperate Asian bamboos: A harbinger of their naturalization in Pacific Northwest coniferous forests?. *Biol. Invasions* **15**, 2081–2093 (2013).
12. Smith, M. C., Gomulkiewicz, R. & Mack, R. N. Potential role of masting by introduced bamboos in deer mice (*Peromyscus maniculatus*) population irruptions holds public health consequences. *PLoS ONE* **10**(4), e0124419 (2015).
13. Swearingen, J. M. & Fulton, J. P. *Plant invaders of mid-atlantic natural areas* (Passiflora Press, 2022).
14. Schnitzler, A. & Essl, F. From horticulture and biofuel to invasion: The spread of *Miscanthus* taxa in the USA and Europe. *EWRS* **55**, 221–225 (2015).
15. Tokarska-Guzik, B., Bzdęga, K., Dajdok, Z., Mazurska, K. & Solarz, W. Invasive alien plants in Poland—the state of research and the use of the results in practice. *Environ. Socio-Econom. Stud.* **9**, 71–95 (2021).
16. EASIN. European Alien Species Information Network – Species Explorer. https://easin.jrc.ec.europa.eu/spexplorer/search/search_paged (2024).
17. NOBANIS. The European Network on Invasive Alien Species (NOBANIS). <https://www.nobanis.org> (2024).
18. GRIIS. Global Register of Introduced and Invasive Species and GRIIS Checklist of Introduced and Invasive Species. Accessed via GBIF.org on 2025–02–15 (2025).
19. van Kleunen, M. et al. The global naturalized Alien Flora (GloNAF) database. *Ecology* **100**, 1–2. <https://doi.org/10.1002/ecy.2542> (2019).
20. GBIF. Global Invasive Species Database. <https://www.gbif.org/dataset/b351a324-77c4-41c9-a909-f30f7268bc4> (2025).
21. Carnevali, L. et al. *Global Register of Introduced and Invasive Species - Italy*. Version 1.6. Invasive Species Specialist Group ISSG. Checklist dataset <https://doi.org/10.15468/n4iafs>. Accessed via GBIF.org on 2025–02–15 (2020).
22. De Groot, M. et al. *Global register of introduced and invasive species - Slovenia*. Version 1.2. Invasive Species Specialist Group ISSG. Checklist dataset <https://doi.org/10.15468/awqzyu>. Accessed via GBIF.org on 2025–02–15 (2020).
23. Essl, F., Rabitsch, W., Wong, L. J. & Pagad, S. *Global register of introduced and invasive species—Austria*. Version 1.5. Invasive Species Specialist Group ISSG. Checklist dataset <https://doi.org/10.15468/ygo6zy>. Accessed via GBIF.org on 2025–02–15 (2020).
24. Gollasch, S., Kühn, I., Wong, L. J. & Pagad, S. *Global register of introduced and invasive species—Germany*. Version 1.6. Invasive Species Specialist Group ISSG. Checklist dataset <https://doi.org/10.15468/yazb1f>. Accessed via GBIF.org on 2025–02–15 (2022).
25. Hilmo, O. et al. *Global register of introduced and invasive species—Norway*. Version 1.16. Invasive Species Specialist Group ISSG. Checklist dataset <https://doi.org/10.15468/9oaedf>. Accessed via GBIF.org on 2025–02–15 (2023).
26. Marchante, H. et al. *Global Register of introduced and invasive species—Portugal*. Version 1.9. Invasive Species Specialist Group ISSG. Checklist dataset <https://doi.org/10.15468/5siv3h>. Accessed via GBIF.org on 2025–02–15 (2020).
27. Maslo, S., Wong, L. J. & Pagad, S. *GRIIS Checklist of Introduced and invasive species—Bosnia and Herzegovina*. Version 1.3. Invasive Species Specialist Group ISSG. Checklist dataset <https://doi.org/10.15468/uuzhvt>. Accessed via GBIF.org on 2025–02–15 (2020).
28. Möller, J., Wong, L. J. & Pagad, S. *Global register of introduced and invasive species—Denmark*. Version 1.6. Invasive Species Specialist Group ISSG. Checklist dataset <https://doi.org/10.15468/1jbiia>. accessed via GBIF.org on 2025–02–15 (2020).
29. Pergl, J., Wong, L. J. & Pagad, S. *Global Register of introduced and invasive species—Czechia*. Version 1.2. Invasive Species Specialist Group ISSG. Checklist dataset <https://doi.org/10.15468/9tcwfe>. Accessed via GBIF.org on 2025–02–15 (2020).
30. Roy, H., Rorke, S., Wong, L. J. & Pagad, S. *Global register of introduced and invasive species—Great Britain*. Version 1.7. Invasive Species Specialist Group ISSG. Checklist dataset <https://doi.org/10.15468/8rzqvw> accessed via GBIF.org on 2025–02–15. (2020).
31. Verloove, F., Groom, Q., Brosens, D., Desmet, P. & Reyserhove, L. *Manual of the Alien plants of Belgium*. Version 1.10. Meise Botanic Garden. Checklist dataset <https://doi.org/10.15468/wtda1m> (2020).
32. CECCD. Council of the European Communities Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. *Off. J. Eur. Commun.* **L206**, 7–50 (1992).
33. Matlaga, D. P. & Davis, A. S. Minimizing invasive potential of *Miscanthus × giganteus* grown for bioenergy: Identifying demographic thresholds for population growth and spread. *J. Appl. Ecol.* **50**, 479–487 (2013).
34. Westoby, M., Falster, D. S., Moles, A. T., Vesk, P. A. & Wright, I. J. Plant ecological strategies: Some leading dimensions of variation between species. *Annu. Rev. Ecol. Syst.* **33**, 125–159 (2002).
35. Pyšek, P. A global assessment of invasive plant impacts on resident species, communities and ecosystems: The interaction of impact measures, invading species' traits and environment. *Glob. Change Biol.* **18**, 1725–1737 (2012).
36. Tang, Y., Washitani, I., Tsuchiya, T. & Iwaki, H. Growth analysis of *Quercus serrata* seedlings within *Miscanthus sinensis* grass canopies differing in light availability. *Ecol. Res.* **5**, 367–376 (1990).
37. Song, Q. N. et al. Accessing the impacts of bamboo expansion on NPP and N cycling in evergreen broadleaved forest in subtropical China. *Sci. Rep.* **7**, 40383 (2017).
38. Xu, Q. F. et al. Rapid bamboo invasion (expansion) and its effects on biodiversity and soil processes. *Glob. Ecol. Conserv.* **21**, e00787 (2020).
39. Pyšek, P. & Prach, K. Plant invasions and the role of riparian habitats: a comparison of four species alien to central Europe. *J. Biogeogr.* **20**, 413–420 (1993).
40. Burkart, M. River corridor plants (Stromtalpflanzen) in Central European lowland: A review of a poorly understood plant distribution pattern. *Glob. Ecol. Biogeogr.* **10**, 449–468 (2001).
41. Richardson, D. M. et al. Naturalization and invasion of alien plants: concepts and definitions. *Divers. Distrib.* **6**, 93–107 (2000).
42. Lieurance, D., Cooper, A., Young, A. L., Gordon, D. R. & Flory, S. L. Running bamboo species pose a greater invasion risk than clumping bamboo species in the continental United States. *J. Nat. Conserv.* **43**, 39–45 (2018).
43. Taylor, A. H., Qin, Z. & Liu, J. Structure and dynamics of subalpine forests in the Wang Lang Natural Preserve, Sichuan, China. *Vegetatio* **124**, 25–38 (1996).
44. Ide, J., Shinohara, Y. H., Komatsu, H., Kuramoto, K. & Otsuki, K. A preliminary investigation of surface runoff and soil properties in a moso-bamboo (*Phyllostachys pubescens*) forest in western Japan. *Hydrol. Res. Lett.* **4**, 80–84 (2010).
45. Canavan, S., Kumschick, S., Le Roux, J. J., Richardson, D. M. & Wilson, J. R. Does origin determine environmental impacts? Not for bamboos. *Plants People Planet* **1**(2), 119–128 (2019).
46. O'Connor, P. J., Covich, A. P., Scatena, F. N. & Loope, L. L. Non-indigenous bamboo along headwater streams of the Luquillo Mountains, Puerto Rico: Leaf fall, aquatic leaf decay and patterns of invasion. *J. Trop. Ecol.* **16**, 499–516 (2000).
47. Suzuki, T. & Nakatsubo, T. Impact of the bamboo *Phyllostachys bambusoides* on the light environment and plant communities on riverbanks. *J. Forest Res.* **6**, 81–86 (2001).
48. Touyama, Y., Yamamoto, T. & Nakagoshi, N. Myrmecofaunal change with bamboo invasion into broadleaf forests. *J. For. Res.* **3**, 155–159 (1998).
49. Ikegami, N., Satake, T., Nagayama, Y. & Inubushi, K. Changes in silica in litterfall and available silica in the soil of forests invaded by bamboo species (*Phyllostachys pubescens* and *P. bambusoides*) in western Japan. *Soil Sci. Plant Nutr.* **60**, 731–739 (2014).

50. Ouyang, M. et al. Effects of the expansion of *Phyllostachys edulis* on species composition, structure and diversity of the secondary evergreen broad-leaved forests. *Biodivers. Sci.* **24**, 649 (2016).
51. Okutomi, K., Shinoda, S. & Fukuda, H. Causal analysis of the invasion of broad-leaved forest by bamboo in Japan. *J. Veg. Sci.* **7**, 723–728 (1996).
52. Vitousek, P. M., D'Antonio, C. M., Loope, L. L. & Westbrooks, R. Biological invasions as global environmental change. *Am. Sci.* **84**, 218–228 (1996).
53. Pimentel, D., Zuniga, R. & Morrison, D. Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecol. Econ.* **52**, 273–288 (2005).
54. Cummins, K. W., Wilzbach, M. A., Gates, D. M., Perry, J. B. & Taliaferro, W. B. Shredders and riparian vegetation. *Bioscience* **39**, 24–30 (1989).
55. Dudgeon, D. The influence of riparian vegetation on macroinvertebrate community structure and function in six New Guinea streams. *Hydrobiologia* **294**, 65–85 (1994).
56. Borowski, P. F. Bamboo as an innovative material for many branches of world industry. *Ann. WULS-SGGW. Forest. Wood Technol.* **107**, 13–18 (2019).

Acknowledgements

The authors would like to sincerely thank Caryn Rickel from the Institute of Invasive Bamboo Research (United States) for help with the identification of the bamboo species. Authors also would like to thank Reviewers for their time and effort that helped improve the manuscript.

Author contributions

Designed the research: A.By. Performed the field work: A.By., A.Bo., M.B. and K.K. Analysed the data: A.By., A.Bo., K.K. and T.L. Wrote the manuscript: A.By., A.Bo., M.B., K.K. and T.L. Edited and revised the manuscript: A.By., K.K. and T.L. The final manuscript was approved by all authors.

Declarations

Competing interests

The authors declare no competing interests.

Additional information

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1038/s41598-025-95582-x>.

Correspondence and requests for materials should be addressed to A.B.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Open Access This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

© The Author(s) 2025

Terms and Conditions

Springer Nature journal content, brought to you courtesy of Springer Nature Customer Service Center GmbH (“Springer Nature”).

Springer Nature supports a reasonable amount of sharing of research papers by authors, subscribers and authorised users (“Users”), for small-scale personal, non-commercial use provided that all copyright, trade and service marks and other proprietary notices are maintained. By accessing, sharing, receiving or otherwise using the Springer Nature journal content you agree to these terms of use (“Terms”). For these purposes, Springer Nature considers academic use (by researchers and students) to be non-commercial.

These Terms are supplementary and will apply in addition to any applicable website terms and conditions, a relevant site licence or a personal subscription. These Terms will prevail over any conflict or ambiguity with regards to the relevant terms, a site licence or a personal subscription (to the extent of the conflict or ambiguity only). For Creative Commons-licensed articles, the terms of the Creative Commons license used will apply.

We collect and use personal data to provide access to the Springer Nature journal content. We may also use these personal data internally within ResearchGate and Springer Nature and as agreed share it, in an anonymised way, for purposes of tracking, analysis and reporting. We will not otherwise disclose your personal data outside the ResearchGate or the Springer Nature group of companies unless we have your permission as detailed in the Privacy Policy.

While Users may use the Springer Nature journal content for small scale, personal non-commercial use, it is important to note that Users may not:

1. use such content for the purpose of providing other users with access on a regular or large scale basis or as a means to circumvent access control;
2. use such content where to do so would be considered a criminal or statutory offence in any jurisdiction, or gives rise to civil liability, or is otherwise unlawful;
3. falsely or misleadingly imply or suggest endorsement, approval, sponsorship, or association unless explicitly agreed to by Springer Nature in writing;
4. use bots or other automated methods to access the content or redirect messages
5. override any security feature or exclusionary protocol; or
6. share the content in order to create substitute for Springer Nature products or services or a systematic database of Springer Nature journal content.

In line with the restriction against commercial use, Springer Nature does not permit the creation of a product or service that creates revenue, royalties, rent or income from our content or its inclusion as part of a paid for service or for other commercial gain. Springer Nature journal content cannot be used for inter-library loans and librarians may not upload Springer Nature journal content on a large scale into their, or any other, institutional repository.

These terms of use are reviewed regularly and may be amended at any time. Springer Nature is not obligated to publish any information or content on this website and may remove it or features or functionality at our sole discretion, at any time with or without notice. Springer Nature may revoke this licence to you at any time and remove access to any copies of the Springer Nature journal content which have been saved.

To the fullest extent permitted by law, Springer Nature makes no warranties, representations or guarantees to Users, either express or implied with respect to the Springer nature journal content and all parties disclaim and waive any implied warranties or warranties imposed by law, including merchantability or fitness for any particular purpose.

Please note that these rights do not automatically extend to content, data or other material published by Springer Nature that may be licensed from third parties.

If you would like to use or distribute our Springer Nature journal content to a wider audience or on a regular basis or in any other manner not expressly permitted by these Terms, please contact Springer Nature at

onlineservice@springernature.com