Received: 8 August 2023 | Accepted: 1 May 2024

DOI: 10.1002/pan3.10670

PEOPLE AND NATURE | BRITISH ECOLOGICAL SOCIETY

RESEARCH ARTICLE

Stakeholders' views on the global guidelines for the sustainable use of non-native trees

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Funding information
Akademie Věd České Republiky, Grant/Award Number: RVO 67985939; Grantová Agentura České Republiky, Grant/Award Number: 19-28807X; MCIN/AEI/10.13039/501100011033 and the FSE+, Grant/Award Number: RYC2022-037905-I; BiodivScen ERANet COFUND Program; Swiss National Science Foundation, Grant/Award Number: 31003A_179491 and 31BD30_184114; Ministry of Education, Youth and Sports of the Czech Republic, Grant/Award Number: CZ.02.2.69/0.0/0.0/18_053/0017850; CAB International; ANID/Basal FB210006; ANID NERC NE/S011641/1; Outside Studies Program (OSP) Fellowship; Czech Science Foundation, Grant/Award Number: 23-05403K; Spanish Ministry of Universities; Margarita Salas of the Universidade de Vigo, Grant/Award Number: UP2021-046; Research Productivity Scholarship-Bolsa de Produtividade em Pesquisa, Grant/Award Number: 302880/2022-4;

Abstract

1. A large number of non-native trees (NNTs) have been introduced globally and widely planted, contributing significantly to the world's economy. Although some of these species present a limited risk of spreading beyond their planting sites, a growing number of NNTs are spreading and becoming invasive leading to diverse negative impacts on biodiversity, ecosystem functions and human well-being. To help minimize the negative impacts and maximize the economic benefits of NNTs, Brundu et al. developed eight guidelines for the sustainable use of NNTs globally—the Global Guidelines for the Use of NNTs (GG-NNTs).
2. Here, we used an online survey to assess perceptions of key stakeholders towards NNTs, and explore their knowledge of and compliance with the GG-NNTs.
3. Our results show that stakeholders are generally aware that NNTs can provide benefits and cause negative impacts, often simultaneously and they consider that their organization complies with existing regulations and voluntary agreements concerning NNTs. However, they are not aware of or do not apply most of the eight recommendations included in the GG-NNTs.
4. We conclude that effectively managing invasions linked to NNTs requires both more communication efforts using an array of channels for improving stakeholder awareness and implementation of simple measures to reduce NNT impacts (e.g.

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Technology Agency of the Czech Republic; Slovenian Research Agency, Grant/Award Number: P4-0107; Italian Ministry of University and Research

Handling Editor: Shonil Bhagwat

via GG-NNTs), and a deeper understanding of the barriers and reluctance of stakeholders to manage NNT invasions.

KEYWORDS
agroforestry, alien species, forestry, invasion risk, online survey, ornamental trees, perceptions, stakeholder engagement, sustainability, tree invasions

1 | INTRODUCTION

Non-native species, also referred to as alien species, are those species whose presence in a region is attributable to human activities that have enabled them to overcome dispersal barriers that define their natural range (Roy et al., 2023). Invasive non-native species, those non-native species that spread in their new ranges, can cause negative ecological and socio-economic impacts. Addressing these impacts requires effective management actions and cooperation between stakeholders. However, the management of invasive non-native species can lead to conflicts, particularly when stakeholders benefiting from non-native species differ from those bearing the costs. These conflicts can hinder the implementation of management actions and strategies. Therefore, achieving workable invasive non-native species management actions relies, to a large extent, on support from relevant stakeholders (Ford-Thompson et al., 2012; García-Llorente et al., 2008; Reed et al., 2009). Engaging stakeholders in the management of non-native species can help identify valuable knowledge and practices, promote awareness, social learning and cooperation, increase mutual trust, reach consensus, gain support and formulate management programmes (Novoa et al., 2018; Shackleton, Adriaens, et al., 2019).

The need for engaging stakeholders to effectively manage non-native species is increasingly recognized (Shackleton, Adriaens, et al., 2019; Shackleton, Richardson, et al., 2019) and is, for example, stipulated by the Convention on Biological Diversity (e.g. CBD/COP/15/L.12, 13 December 2022), the European Strategy on Invasive Alien Species (Genovesi & Shine, 2004) and several national and regional non-native species management strategies around the world (Government of Canada, 2004). Stakeholder engagement is crucial when non-native species that are targeted for management are also conflict species (Novoa et al., 2018). For example, Novoa et al. (2016) found that stakeholders who benefit from invasive cacti (family *Cactaceae*) in South Africa had more positive perceptions towards them than those who suffered the negative impacts of cactus invasions. However, a two-day-long stakeholder workshop was effective in increasing stakeholders' understanding of both the benefits and impacts of invasive cacti and improving their acceptance of, and involvement in, cactus management. Similarly, Bryce et al. (2011) demonstrated that involving stakeholders in the management of invasive mink (*Neovison vison*) in Scotland improved the efficiency and effectiveness of control efforts. Likewise, the support of local stakeholders has been essential for the management of invasive pine trees (*Pinus* spp.) in Southern Brazil (Dechoum et al., 2019). Stakeholder consultations are also crucial for the two international and independent forest certification systems (FSC and PEFC) in the processes of developing standards for forest stewardship, which include requirements for management of invasive species (e.g. FSC STD 01-001 in Principle 10; PEFC ST 1003:2018 in Criterion 8.4.5).

The use of non-native trees (NNTs) in agroforestry, forestry, gardening, landscape architecture and urban forestry has led to conflicting views and mixed perceptions among different stakeholders (Dickie et al., 2014; Kull & Tassin, 2012; Low, 2012; Sitzia et al., 2016; van Wilgen & Richardson, 2014; Vítková et al., 2017). NNTs can have a wide range of benefits, including climate-change mitigation, the reduction of sand drift hazards and the production of fibre, firewood and timber (Castro-Díez et al., 2019). Several NNTs are also charismatic and aesthetically pleasing in their new habitats (Dickie et al., 2014; Jarić et al., 2020). Moreover, many NNTs used in forest plantations have faster growth rates, broader climate tolerance and better resistance to pathogens and pests than native species (Seidl et al., 2018), and some have been hybridized and artificially selected to improve these attributes (Caires et al., 2019; Rubilar et al., 2020). For these reasons, NNTs are widely introduced and planted and contribute significantly to the world economy (Bastin et al., 2019; Brockerhoff et al., 2008; Martin et al., 2021). However, some of the traits that make NNTs desirable are also associated with invasion risk (e.g. fast growth rates, high dispersal and high pathogen resistance; Pyšek & Richardson, 2007). It is therefore not surprising that a growing number of NNTs are reported to spread beyond their planting areas. These NNTs can become invasive in some regions and cause a wide range of negative environmental and socio-economic impacts, such as displacing native species, modifying fire regimes by increasing fuel availability and flammability, reducing water availability, favouring the introduction and proliferation of other non-native species such as insect pests and impacting livelihood practices and human well-being (Richardson et al., 2014). For example, several wattle (*Acacia* Mill. spp.), gum (*Eucalyptus* L'Hér spp.), pine (*Pinus* L. spp.), mesquite (*Prosopis* L. spp.) and locust (*Robinia* L. spp.) species, which are extensively used for timber production, agroforestry or silviculture in many areas of the world, are also highly invasive, causing negative social-ecological impacts (Kull et al., 2011; Moran et al., 2000; Shackleton et al., 2014). The Tasmanian blue gum (*Eucalyptus globulus* Labill.) for instance, which is widely used in forest plantations along the Atlantic coast of the

Iberian Peninsula, also forms dense stands that modify water and fire regimes (Dehnen-Schmutz et al., 2010; Hurley et al., 2016; Touza et al., 2014) and impact conservation efforts in protected areas (Deus et al., 2022; Queirós et al., 2020). Despite these negative impacts, *E. globulus* was included much later into official lists of invasive non-native species in Spain or Portugal than other invasive species without economic benefits.

In Europe, almost 80% of tree species in forest plantations are non-native (FAO, 2020; FOREST EUROPE, 2020), with the European forestry sector reporting 150 NNT species that are used (Brus et al., 2019). Of these, the most abundant are *Robinia pseudoacacia* L., *E. globulus*, *Picea sitchensis* (Bong.) Carr., *Pseudotsuga menziesii* (Mirb.) Franco and *Pinus contorta* Douglas ex Loudon, all of which are invasive somewhere in Europe or elsewhere in the world (Calviño-Cancela & Rubido-Bará, 2013; Knight et al., 2001; Nuñez et al., 2017; Nygaard & Øyen, 2017; van Loo et al., 2019; Vítková et al., 2017). Aiming to encourage European national authorities to prevent and mitigate the impacts of invasive NNTs, the Standing Committee to the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention, Council of Europe), acting under the terms of Article 14 of the Convention, adopted the Code of Conduct on Invasive Alien Trees (Brundu & Richardson, 2016). Furthermore, it recommended (Rec. no. 193/2017) that Contracting Parties take the European Code of Conduct into account while drawing up other relevant codes or, where appropriate, draw up national codes of conduct on invasive NNTs. The committee also recommended that Contracting Parties collaborate as appropriate with the actors involved in forestry activities in implementing and helping disseminate good practices and codes of conduct aimed at preventing and managing the introduction, release and spread of invasive non-native trees. It also asked Contracting Parties to keep the Standing Committee informed of measures taken to implement the recommendation. The European Code of Conduct comprises 14 principles and is addressed to all Contracting Parties, relevant stakeholders and decision-makers in the 46 Member States of the Council of Europe, including the forestry sector and associated professionals in the management of NNTs. Furthermore, the Recommendation No. 216 (2022) of the Standing Committee, adopted in December 2022, warns on the potential risks associated with the use of NNTs that pose high invasion risk incorrectly labelled as a "nature-based solution to mitigate climate change."

With the aim of expanding and generalizing the geographical context of most of the principles and recommendations of the European Code of Conduct on Planted Forest and Invasive Alien Trees, Brundu et al. (2020) proposed a set of Global Guidelines for the use of NNTs (hereafter GG-NNTs; Figure 1) that addresses a broader platform of relevant stakeholders globally. Despite these existing international guidelines, studies or projects that identify stakeholders, create awareness and assess their perceptions of the GG-NNTs are lacking. In this study, we aimed to fill this gap by: (1) assessing the perceptions of different stakeholders affected by NNTs or influencing their use, regulation and management towards NNTs and (2) exploring their compliance with the GG-NNTs.

2 | METHODOLOGY

2.1 | Identifying stakeholders

Aiming to find contact details of stakeholders that use and/or manage NNTs (i.e. the e-mail addresses provided on their websites), we conducted a comprehensive Google web search using combinations of the name of each of 195 countries (i.e. member states and non-member observed states of the United Nations) with one of the following keywords: agroforestry, forest, forestry, timber, "plant* trees", "forest plantation", "ornamental tree", "urban forest*", tree AND landscape, tree AND garden. Searches were mainly done in English and Spanish. Co-authors added additional contacts from their respective countries (i.e. Argentina, Australia, Austria, Brazil, Chile, Czech Republic, Ecuador, Finland, France, Israel, Italy, Portugal, Slovenia, South Africa, Switzerland, United Kingdom, the United States of America). Overall, we identified 753 relevant stakeholder institutions. We divided all identified stakeholders into seven groups according to the sectors they can be associated with: (1) aesthetics, which includes stakeholders using NNTs for their aesthetic attributes, including landscape architects or generally stakeholders working in urban greenery (we acknowledge that urban greenery aims to provide other benefits beyond aesthetics, such as providing shade, stimulating biodiversity and improving air quality); (2) environmental improvement, includes stakeholders planting NNTs with the aim of improving the environment, such as those planting NNTs to combat climate change and degradation or to stabilize sand dunes; (3) research in forestry; (4) forest industry and forest production, that is stakeholders using NNTs to obtain wood and non-wood forest products including agroforestry and nurseries; (5) research in nature conservation; (6) nature conservation, including conservation managers and practitioners; and (7) other, those that did not fit any of the other categories (e.g. environmental consultancies and governmental agencies).

2.2 | Online survey

The questionnaire (Supporting Information) was comprised of three sections: (1) a section aimed to assess how respondents perceive NNTs, (2) a section designed to assess whether stakeholders comply with the GG-NNTs and (3) a section aimed at collecting sociodemographic information about the respondents and their institution. First, respondents were asked whether their organization was involved in studying, using, or managing NNTs. Aiming to assess their perceptions towards NNTs, respondents were asked to provide three words that immediately came to their mind when they thought about NNTs and to score each word on a scale from −3 (very negative) to +3 (very positive). To identify levels of consensus and disagreement, the questionnaires also included five statements relating to the negative impacts and benefits of NNTs, whether the use of native and non-invasive NNTs

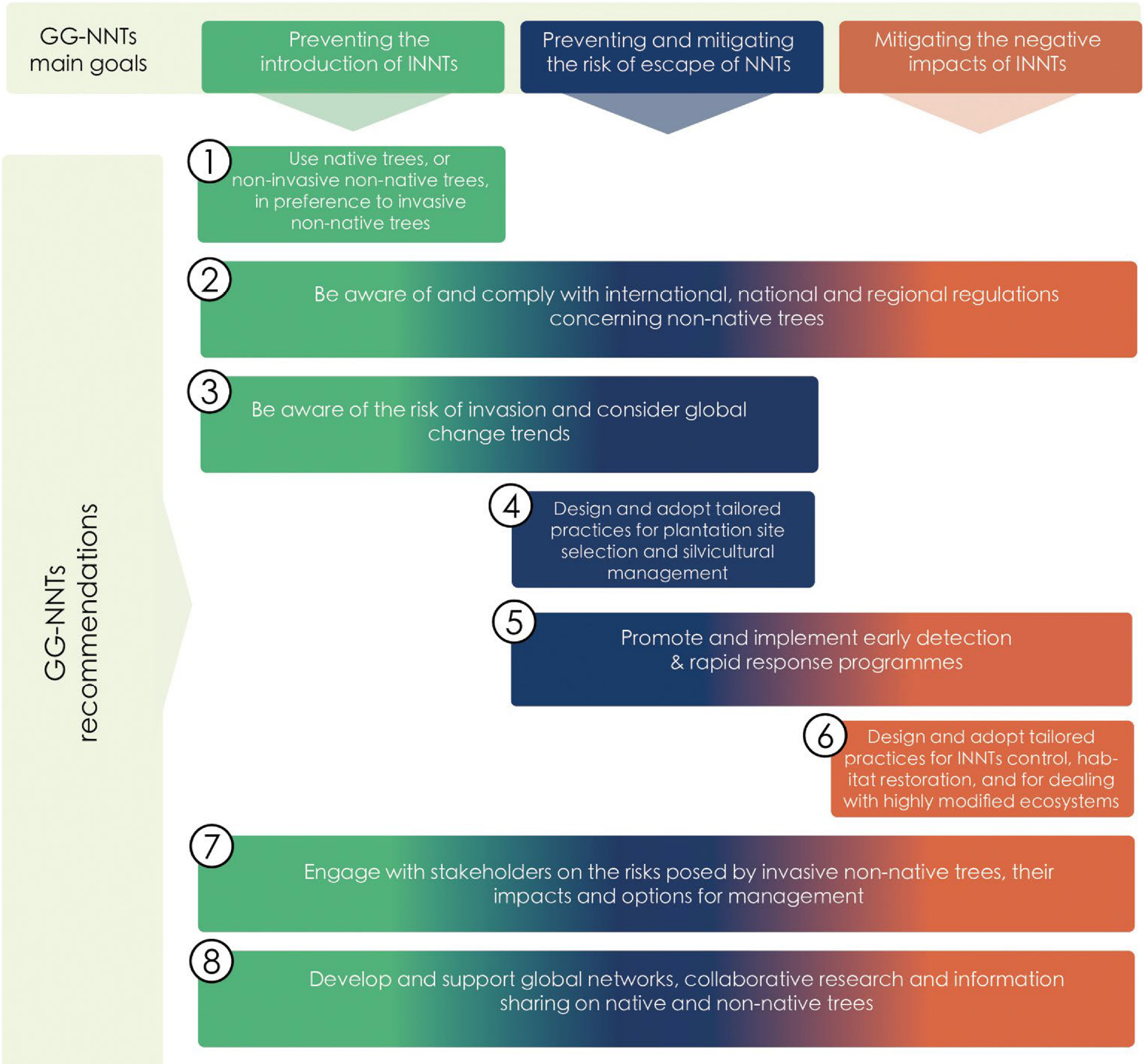

FIGURE 1 Main goals and recommendations of the Global Guidelines for the use of Non-Native Trees (GG-NNTs; reproduced with permission from Brundu et al., 2020). INNTs, Invasive Non-Native Trees.

should be preferred over the use of invasive NNTs, and about the need for stakeholder engagement. Five responses were offered for each statement (Likert scale): *strongly agree*, *agree*, *neutral*, *disagree* and *strongly disagree*. Likert scales are a common method in social science research (Nemoto & Beglar, 2014). The survey included nine additional questions to explore whether stakeholders comply with the GG-NNTs, their gender (female, male, other), age class (18–25, 26–35, 36–45, 46–55, 56–65, >65), sector (aesthetics, environmental improvement, research in forestry, forest production, research in conservation, conservation, other) and region (Africa, Asia, Europe, North America, South America, or Global, i.e., not focused on a single continent). Questionnaires were translated into Czech, English, Italian, Portuguese, Russian and Spanish, as these were the languages spoken by most of the identified stakeholders and by the co-authors of this study. Online questionnaires were created in Microsoft Forms. To evaluate the comprehensibility, clarity, length and accuracy of the questions, we pilot-tested the surveys with a few stakeholders before disseminating it to all potential respondents.

We e-mailed all identified stakeholder institutions and asked them to complete an online survey if they had any involvement with NNTs. E-mails were sent in Czech, Dutch, English, Italian, Portuguese, Russian and Spanish. As many of the identified stakeholder institutions are large and focus on many aspects of NNTs, for completion of the survey, we requested that someone knowledgeable and engaged with the use and/or management of NNTs at the institution should complete the survey. When we received no answer, we sent up to four reminders. We also followed a snowballing approach, and asked stakeholders whether they work closely with other relevant stakeholders, and whether they could forward the link of the survey to them. Stakeholders were informed, and gave consent, that the results of the survey would be presented in a scientific publication (see Supporting Information). No ethical approval was required from the research centre leading the research. Surveys were completed between April 2021 and May 2022.

2.3 | Data analysis

All analyses and data visualization were performed using the R statistical software (v4.0.4.). Aiming to identify levels of consensus or disagreement towards different aspects of NNTs, we used the package 'agrmt' 1.42.4 (Ruedin, 2020) to calculate polarization scores for each Likert statement. Polarization scores range from 0 to 1, with values closer to 0 indicating increased consensus and values closer to 1 indicating increased disagreement. We then classified polarization scores as low, moderate and high according to their upper and lower quartiles (i.e. low polarization ≤0.20 and high polarization ≥0.31; Ruedin, 2020).

Aiming to identify response patterns, we performed exploratory factor analysis (EFA) on half of the data set (randomly selected), with the package 'psych' 1.9.12 (Revelle, 2019). We used the results to test for construct validity in confirmatory factor analysis (CFA). We evaluated internal consistency and the appropriateness of the data for factor analysis using Cronbach's alpha reliability coefficient and the Kaiser–Meyer–Olkin measure of sampling adequacy (KMO). These scores were found to be adequate for further analyses. To identify the optimal number of factors, we utilized the nScree() function from package 'nFactors' 2.1 (Raiche & Magis, 2022; Figure S1), which calculates the level of agreement between multiple eigenvalue-based methods. When multiple solutions showed a comparable level of agreement between methods, we selected the solution with the highest number of items loading very strongly (≥0.6) on each factor (Furr, 2011) and the highest number of factors. After identifying the optimal number of factors, we generated the factor loadings of all statements with maximum likelihood extraction with Oblimin rotation to identify statements that did not load strongly on any factor (<0.45, Appendix, Table S1). We excluded statements that loaded weakly (<0.4) and then refitted the model to check for consistency.

After obtaining the factorial structure from the EFA, we applied this to the fitting data set (second half of the data) to test for construct validity through CFA. We excluded statements with weak loadings in the CFA (<0.45) to obtain simple factorial structures as done in the EFA (Sandbrook et al., 2019). The CFA and multiple goodness-of-fit indices were calculated with the package 'lavaan' 0.6–9 (Rosseel, 2012) to determine to what extent the factorial structure from the EFA fitted the other half of the response database. The CFA indices demonstrated a satisfactory fit (Table S2); we therefore ran a factorial analysis (maximum likelihood and Oblimin rotation) on the full data set based on the structure from the CFA with the factor. scores() function from the 'psych' package 1.9.12 (Revelle, 2019). Based on this, five distinct factors were retained (see Section 3). To comprehensively assess the main attitude of the respondents within each construct, we also generated fictional scores for a hypothetical respondent who remained neutral towards all statements, following Sandbrook et al. (2019).

We used multiple regression analysis to explore whether response patterns to the identified factors vary according to the respondents' sociodemographic characteristics (i.e. gender, age class, sector, region and perception towards NNTs as negative, including very negative, positive, including very positive, or neutral; Figure 2). For each variable, we used the category with the highest number of responses as the baseline (Wood et al., 2022).

3 | RESULTS

3.1 | Response group profile

We received 286 responses to the online survey, corresponding to a 37.9% response rate. There were more male (69.9%) than female (28.3%) respondents (Table 1). Most respondents worked in academic (33.5%) or public (32.0%) organizations, compared with those working in NGOs (16.0%) or the private sector (18.5%). Respondents worked primarily in the forest production sector (25.2%), forestry research (19.2%), research in conservation (17.8%) and conservation practice/management (13.6%). Most respondents worked at a national scale (52.4%) and in Europe (60.5%).

3.2 | Stakeholders' perceptions towards NNTs

All respondents answered that their organizations were involved in studying, using or managing NNTs. Generally, stakeholders from the aesthetics, environmental improvement, research in forestry and forest production sectors had more positive attitudes towards NNTs than stakeholders from the conservation management or research in conservation sectors (Figure 2).

3.3 | Consensus and polarization

There was a general agreement and low polarization (good consensus) that NNTs provide economic benefits but can also harm the environment; risk assessments should be performed before introducing NNTs; and stakeholders should be engaged in the management of NNTs (Figure 3). There was moderate polarization in views on whether NNTs provide social and/or health benefits and cause socio-economic losses; whether it is better to plant native trees than NNTs, and whether only non-invasive NNTs should be used; and if a planted NNT did not spread from the plantation site after a long time, it would not do so in the future. Finally, there was high polarization (low consensus) in the views on whether NNTs provide benefits to the environment, and whether such benefits cannot be

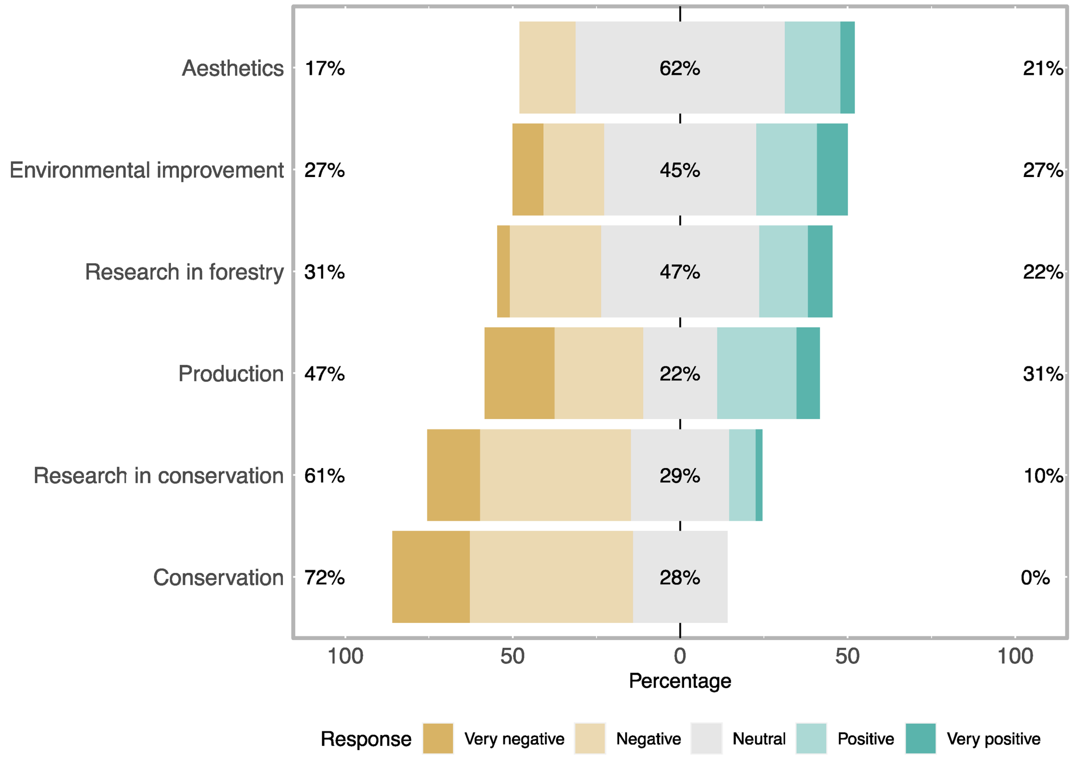

FIGURE 2 Stakeholders' perceptions of non-native trees (NNTs) according to the sector they work in. Percentages indicate the percentage of stakeholders from each sector that scored the first three words that immediately came to their mind when they thought about NNTs as negative (left), neutral (centre) and positive (right).

adequately provided by native trees; it is better to plant NNTs than no trees; and that potentially invasive NNTs can be used if their risk of invasion can be managed effectively.

3.4 | Effects of sociodemographic and institutional backgrounds on respondents' attitudes

Five main factors were retained. The first factor identified was related to the benefits of NNTs (including the statements 'NNTs can provide benefits to the environment', 'NNTs can provide economic benefits' and 'NNTs can provide social and/or health benefits'). The second factor was related to their negative impacts ('NNTs can harm the environment' and 'NNTs can cause socioeconomic losses'). The third factor concerned whether the use of NNTs should be properly managed ('A risk analysis should be performed before planting a NNT that is not yet present in an area' and 'Effective management of the risks of NNTs requires collaboration with all positively and negatively affected stakeholders'). The fourth factor we retained was related to whether it is acceptable to use NNTs that pose low invasion risk ('If it is not possible to use NTs, we should use non-invasive NNTs over invasive NNTs' and 'We should only use NNTs that pose no risk of invasion'). The last factor refers to whether it is acceptable to use NNTs regardless of their invasion risk ('It is acceptable to use NNTs that pose a risk of invasion if this risk can be managed effectively' and 'If there are not enough propagules/stock of NTs available for reforestation programs, it is better to plant NNTs than to plant no trees'). In some cases, sociodemographic characteristics significantly influenced the way participants responded to these factors (Figure 4).

The gender of the respondents did not have a significant influence on their responses to any of the factors. However, compared with the 46–55 group, respondents between 56 and 65 years old were more likely to agree with the benefits factor, respondents older than 65 years were more likely to disagree with the negative impacts factor, and respondents between 26–35 and 56–65 years old were more likely to agree with the factor suggesting that it is acceptable to use all NNTs (Figure 4). Compared with respondents from the production sector, respondents from the research in forestry and environmental improvement sectors were more likely to answer positively regarding the benefits of NNTs, while respondents from the conservation sector were more inclined to agree with the negative impacts factor. Researchers in conservation were more likely to answer positively to whether it is acceptable to use non-invasive NNTs. Researchers in forestry were more inclined to agree that it is acceptable to use all NNTs regardless of their invasion risk, while respondents from the aesthetics and conservation sectors were more likely to disagree with this factor (Figure 4). Compared with European respondents, respondents from Asia and South America were more likely to disagree with the questions on negative impacts, whereas those from Africa were more likely to agree with the questions related to whether the use of NNTs should be managed and it is

TABLE 1 Sociodemographic characteristics of the respondents ($n = 286$).

Sociodemographic variable	Category	Number of respondents	Percentage (%)
Gender	Female	81	28
	Male	200	70
	Other	5	2
Age	<25	5	2
	26–35	40	14
	36–45	81	28
	46–55	84	29
	56–65	61	21
	>65	14	5
Organization type	Academic	94	33
	NGO	45	16
	Private	52	18
	Public	90	31
Sector	Aesthetics	24	8
	Environmental improvement	11	4
	Research in forestry	55	19
	Forest production	72	25
	Research in conservation	51	18
	Conservation	39	14
	Other	34	12
Scale	International	78	27
	National	150	52
	Sub-national	58	20
Region	Africa	35	12
	Asia	26	9
	Europe	173	60
	North America	7	2
	South America	36	13
	Global	8	3

acceptable to use all NNTs. Finally, compared to respondents with a negative perception of NNTs, respondents with a neutral or positive perception of NNTs were inclined to respond more positively to the benefits question and to the factor on whether it is acceptable to use all NNTs, while respondents with positive perceptions of NNTs were more likely to answer negatively to the negative impact questions.

3.5 | Stakeholders' compliance with recommended regulations and guidelines

Approximately half of all respondents (53%) answered that they were aware of regulations, guidelines or agreements concerning NNTs in their geographical areas. Moreover, 60% of respondents answered that their organization complies with existing regulations or voluntary agreements concerning NNTs (Figure 4). Of all respondents, 71% answered that their organization takes the risk of NNTs becoming invasive into account when selecting tree species. Only 12% of the respondents from the aesthetic sector answered that their organization has a system to reduce the risk of NNTs escaping from planted areas. Half of the respondents from the environmental improvement (55%) and conservation (49%) sectors, and less than half of the respondents from the other sectors (35%, 29% and 38% of the respondents from the production, research in conservation and research in forestry, respectively), answered that their organization has such a system in place. Similarly, 17% of the respondents from the aesthetic sector answered that their organization monitors the surroundings of plantation sites to detect the escape of NNTs, while 28%–47% respondents from the other sectors answered positively to this statement. A small percentage of respondents (e.g. 18% of respondents within the environmental sector and 34% of all respondents) answered that their organization controls NNTs growing beyond plantation sites. Respondents from the aesthetics and from the environmental improvement sectors (30% and 36%, respectively) answered that their organization is involved in the restoration of sites previously occupied by NNTs, while this percentage was higher for

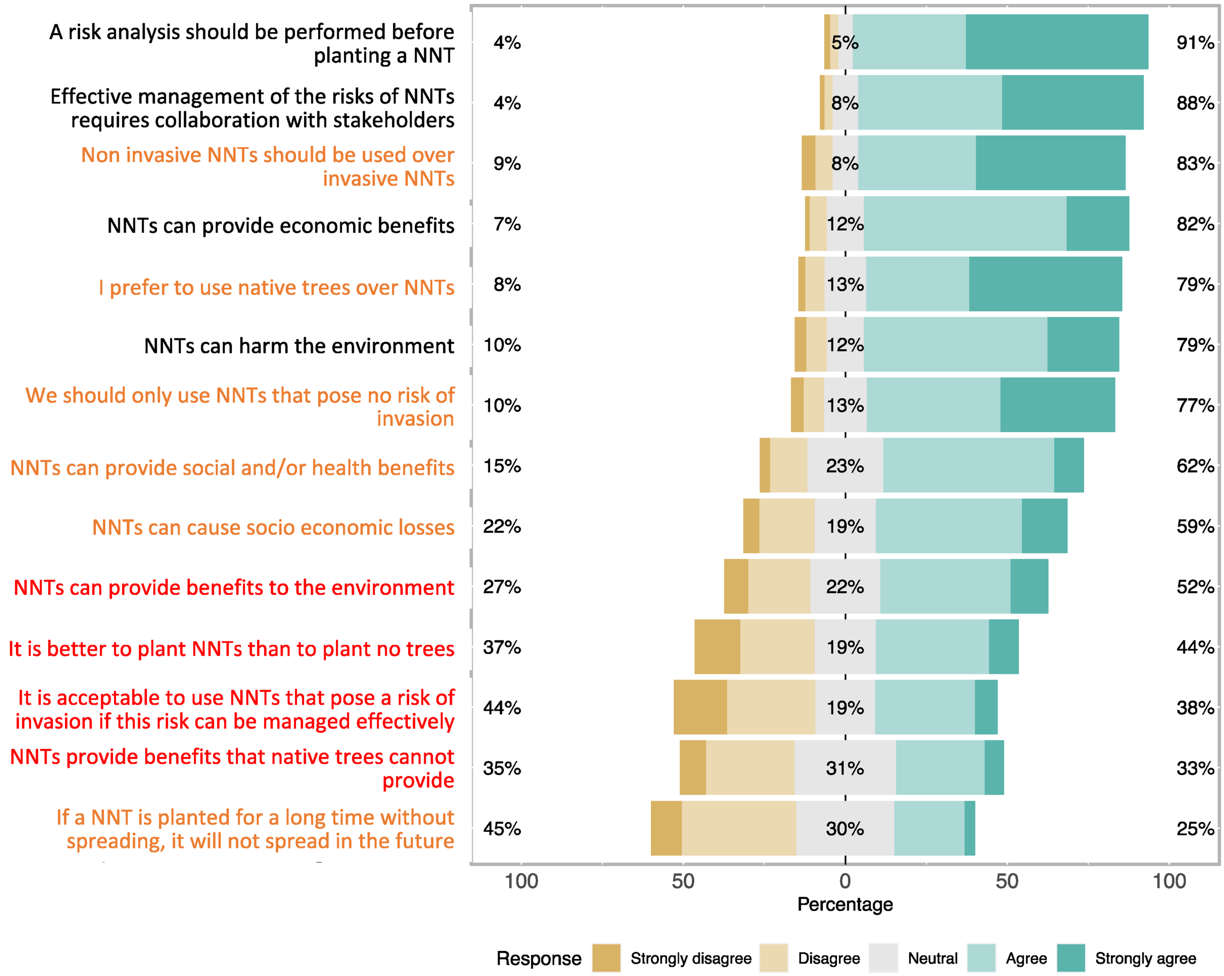

FIGURE 3 Level of agreement and polarization of survey respondents on 14 Likert (ranking) statements. Statements with low polarization (i.e. greater consensus among respondents) are indicated in black, medium polarization in orange, and high polarization (i.e. high disagreement among respondents) in red.

the respondents classified within the conservation (77%), production (60%), research in conservation (65%) and research in forestry (47%) sectors. Most stakeholders from the research in conservation (73%) and conservation sectors (64%) answered that their organization reports information on the management of NNTs to other organizations, while this trend was not observed in other sectors. Most respondents (72%) answered that their organization is involved in raising public awareness. Finally, respondents often collaborate with other organizations on issues related to the use of NNTs (68% of respondents answered yes to this question; Figure 5).

4 | DISCUSSION

In this study, we assessed the attitudes of 286 stakeholders towards NNTs. Our results suggest that stakeholders who benefit from NNTs or seek to promote their usefulness had more positive attitudes towards NNTs compared with other stakeholders. Similarly, stakeholders from the forestry and environmental improvement sectors who, for example, use NNTs for combating climate change, agreed more that NNTs can provide benefits, while stakeholders from the conservation sector agreed more often that NNTs can cause negative impacts. Despite these observed differences, our data showed a general agreement among stakeholders that although NNTs provide economic benefits, they can also harm the environment. This suggests that stakeholders affected by NNTs or influencing their use, regulation and/or management globally may have a general understanding that NNTs can have both benefits and costs, which is fundamental for gaining their support to effectively manage NNTs (Novoa et al., 2018). However, our data also indicated disagreement among stakeholders with regards to whether NNTs provide social, health and environmental benefits, can provide benefits that native trees cannot provide, and can be beneficial for the environment. These disagreements are a potential source of conflict.

Achieving support for the management of invasive NNTs depends, to a large extent, on integrating stakeholders' perspectives and dealing with potential conflicts of interest (Novoa et al., 2018). Therefore, we also assessed respondents' level of agreement with the GG-NNTs, which consists of eight voluntary recommendations aiming to maximize the benefits of NNTs while minimizing current

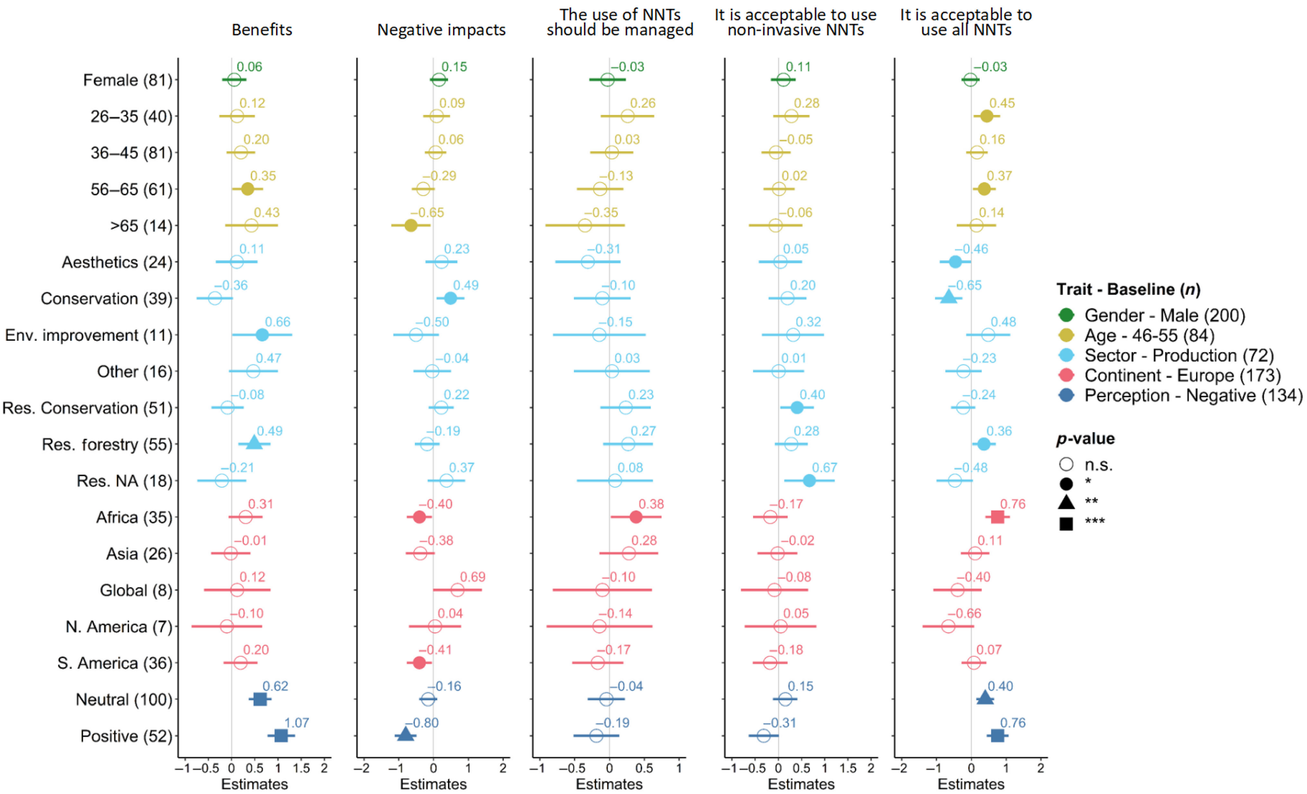

FIGURE 4 Relationship between sociodemographic characteristics of respondents and their response patterns in each of the five factors related to the benefits and negative impacts of non-native trees (NNTs) and to whether the use of NNTs should be avoided, it is acceptable to use NNTs that pose low invasion risk, or it is acceptable to use all NNTs. Shapes and horizontal lines indicate the differences from baseline logits [vertical grey line] at 95% CI values. Positive and negative estimates indicate, respectively, whether respondents agree or disagree to a greater extent than the comparison/baseline group. Filled shapes indicate significant differences from the baseline group (*$p<0.05$; **$p<0.01$; ***$p<0.001$). The categorical group with the greatest number of respondents is the baseline group for each of the sociodemographic variables. Numbers in parentheses indicate the number of respondents in each group. Only groups with more than five respondents were used.

and future NNT invasions and their associated negative impacts (Brundu et al., 2020; Figure 1). Our results suggest that although half of the respondents were not aware of the existence of any regulations, guidelines, or agreements concerning NNTs, they felt that their organizations might be complying with at least some of the recommendations included in the GG-NNTs. For example, the first guideline of the GG-NNTs recommends using native trees or non-invasive NNTs in preference to invasive NNTs, and only using NNTs if their invasion risk can be managed effectively. Accordingly, our results suggest that stakeholders across sectors generally agree that it is better to use native trees over NNTs, NNTs that pose no risk of invasion over invasive NNTs, and that only NNTs that pose no risk of invasion should be used. Moreover, in accordance with some GG-NNT recommendations, most stakeholders responded that their organizations aim to raise public awareness and collaborate with other organizations on issues related to NNTs. Yet, our results also suggest that many stakeholders do not agree with most recommendations included in the GG-NNTs. For example, we found high polarization (i.e. high disagreement) among stakeholders in the view that potentially invasive NNTs can be used as long as their risk of invasion in the given region can be managed effectively. This view is shared by the FSC (https://fsc.org/en/document-centre/documents/resource/392) and PEFC (https://cdn.pefc.org/pefc.org/media/2019-01/b296ddcb-5f6b-42d8-bc98-5db98f62203e/6c7c212a-c37c-59ee-a2ca-b8c91c8beb93.pdf), the two international and independent forest certification systems that deal with sustainable and responsible forest management.

Our results also suggest that stakeholders believe they are complying with existing regulations and guidelines, but half responded that they were not aware of the existence of the GG-NNTs or any other guidelines or regulations concerning NNTs. Therefore, there is a critical need to enhance communication efforts to inform stakeholders and promote and co-adapt the GG-NNTs. We suggest that the development of similar future guidelines and initiatives targeting the use of non-native species should be done in collaboration with stakeholders. This could increase uptake and awareness (Novoa et al., 2018).

We found moderate polarization in the views that there is a risk of NNTs becoming invasive even if they have not yet spread from the sites where they were first planted. These results suggest the need to implement awareness campaigns to inform stakeholders that NNTs often experience long lag phases between

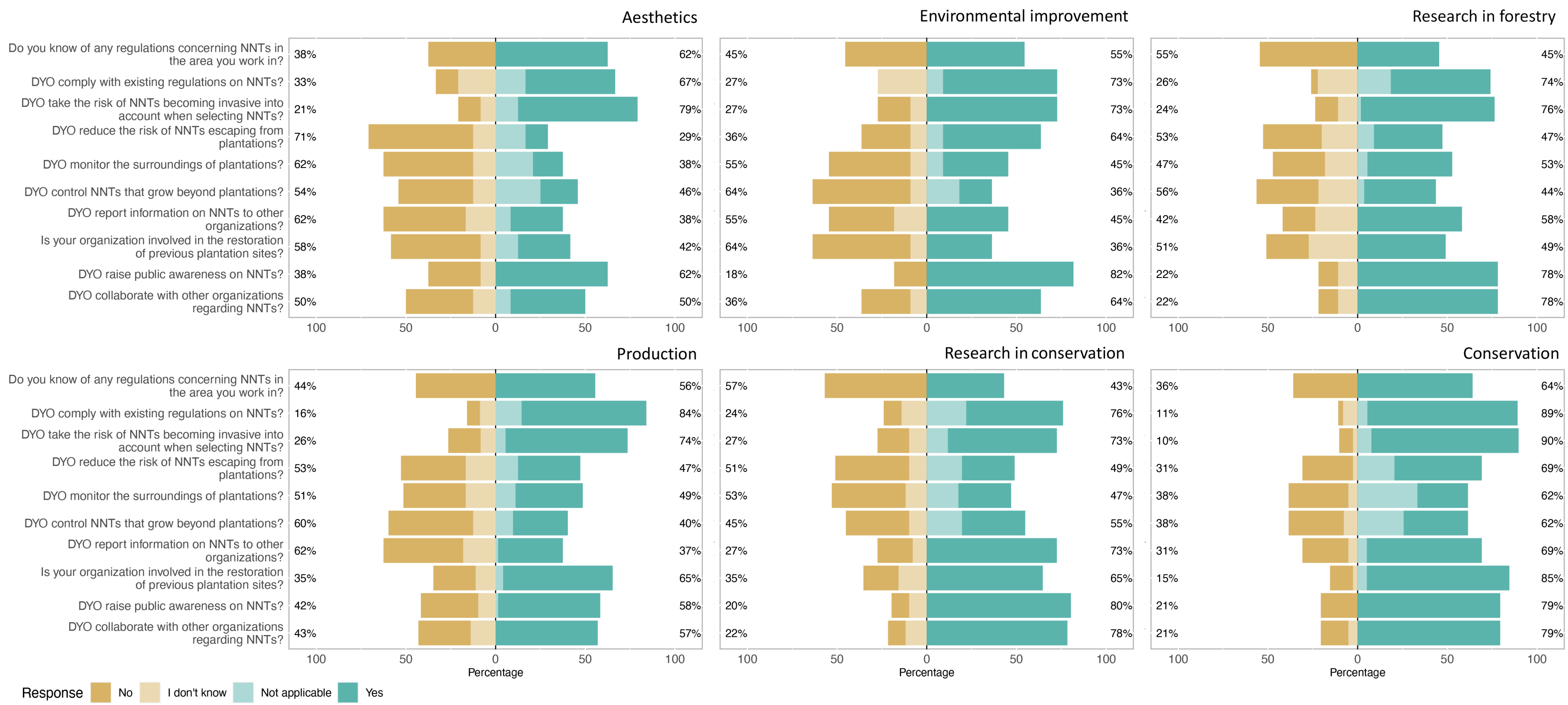

FIGURE 5 Stakeholders' compliance with the GG-NNTs according to the sector they work in. DYO = 'Does your organization'. [Correction added on 17 June, after first online publication: The formatting of Figure 5 has been corrected.]

introduction and naturalization or invasion (of up to 300 years or longer, Kowarik, 1995) and that climate change and land use change may increase the opportunities of NNTs for spread (Aubin et al., 2018; Vaz et al., 2019). As suggested by Brundu et al. (2020), sustainable forest management certification schemes (such as FSC and PEFC) might play an important role in the development of such awareness campaigns. Furthermore, there is scope to promote novel risk-assessment schemes that adequately consider site-specific variations in the invasion risk and impacts of NNTs or the extent of affected areas, such as the one proposed by Bindewald et al. (2021).

Most stakeholders are not following the recommendations of designing and adopting tailored practices to reduce the risk of spread of NNTs from plantations (Recommendation 4) and promote early detection and rapid response (Recommendation 5), control and restoration programs (Recommendation 6). This was especially true for stakeholders within the aesthetics sector. An exception was the involvement of stakeholders from the conservation, research in conservation and forestry production sectors in the restoration of previous plantation sites.

Despite contacting many stakeholders involved in forestry and ornamental use of trees in North America, it is noteworthy that few respondents were from the region (2%). This might be because only few North American organizations study, use, or manage NNTs. Moreover, some of the fast-growing NNT species that have been promoted globally (e.g., *Eucalyptus* spp.) lack frost tolerance and therefore are not suitable for many North American regions. Of the more than 23 million ha of planted forests in the United States (Smith et al., 2004), most major forest plantations use native species (Payn et al., 2015). For example, the southern United States produces 15%–20% of global industrial wood fibre almost entirely from native *Pinus* spp. (Cubbage et al., 2005). However, urban tree plantings in North America, such as in the northeastern United States (Doroski et al., 2020), are composed significantly of NNT species like Norway maple (*Acer platanoides* L.). Further, Lugo et al. (2022) reported that the forest land area in the coterminous United States with NNTs is 7.6 million ha and expanding by more than 200,000 ha annually suggesting the need for a better understanding and adherence to the GG-NNTs.

5 | CONCLUSIONS

Overall, our results suggest that the majority of respondents appear to be largely unaware of, or non-compliant with, most of the recommendations outlined in the GG-NNTs although they do feel that they are aware of the existence of other regulations. This lack of awareness and compliance can increase the occurrence and severity of the negative environmental and socioeconomic impacts caused by NNTs globally (Richardson et al., 2014).

The GG-NNTs are currently only available in the format of a research paper, a form of communication which typically reaches, is read and understood only by the research community. Therefore, it is crucial to invest effort in communicating and disseminating the recommendations globally. Such information should reach all stakeholders who benefit from NNTs or seek to promote their usefulness, as well as those who suffer the costs of NNTs or seek to reduce their negative impacts. Our results also suggest that these efforts might be successful and encourage the adoption and compliance of stakeholders with the GG-NNTs: most stakeholders are already aware of the potential benefits and costs associated with NNTs, engaged in creating awareness of issues related to NNTs, and open to collaboration with stakeholders from other regions and sectors.

Ensuring compliance is generally an important and limiting aspect of any voluntary code of conduct addressing invasive species management (Hulme et al., 2018). Without buy-in from stakeholders, such codes of conduct are of little use. Therefore, there is an urgent need to raise awareness among stakeholders about the existence of global policies and regulations, and to encourage their adoption and compliance to reduce risks associated with tree invasions (Novoa et al., 2018). It remains unclear which type of campaign can most effectively increase awareness of non-native species among stakeholders (Haley et al., 2023; but see Verbrugge et al., 2014). This highlights the need to invest more effort in this topic.

AUTHOR CONTRIBUTIONS

Our study brings together authors from a number of different countries, including scientists based in the countries where the survey was distributed. All authors were engaged early on with the research and study design to ensure that the diverse sets of perspectives they represent was considered. Ana Novoa, Giuseppe Brundu, David M. Richardson, Ross T. Shackleton and Urs Schaffner conceived the ideas and designed the methodology. Ana Novoa compiled the first list of stakeholders, which was further populated by Antonio Brunori, Thomas Campagnaro, Laura Celesti-Grapow, Michele Dechoum, Katharina Dehnen-Schmutz, Jean-Marc Dufour-Dror, Heinke Jäger, Jasmin Joshi, Marion Karmann, Katharina Lapin, Mauro Masiero, Jana Pyšková, Ross T. Shackleton, Joaquim S. Silva, Tommaso Sitzia, Michaela Vítková, Yitbarek Tibebe Weldesemaet, Marjana Westergren, Barbara Langdon and Aníbal Pauchard. Ana Novoa, Jasmin Joshi, Thomas Campagnaro, Michele Dechoum, Annabel Porté, Katharina Lapin and Michaela Vítková translated the questionnaires. Ana Novoa and Giovanni Vimercati analysed the data and created the figures. Ana Novoa led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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ACKNOWLEDGEMENTS

We thank David Coyle and Sandy Liebhold for their valuable insights. A.N., P.P. and J. Pergl acknowledge funding from EXPRO grant no. 19-28807X (Czech Science Foundation). A.N., P.P. and D.M.R. acknowledge funding from long-term research development project RVO 67985939 (Czech Academy of Sciences). A.N. was supported by the MCIN/AEI/10.13039/501100011033 and the FSE+ (Grant No. RYC2022-037905-I). G.V. acknowledges funding through the 2017–2018 Belmont Forum and BIODIVERSA joint call for research proposals, under the BiodivScen ERANet COFUND Program, through the InvasiBES (http://elabs.ebd.csic.es/web/invasibes), with the Swiss National Science Foundation (SNSF grant numbers 31003A_179491 and 31BD30_184114). D.M.R. acknowledges support from Mobility 2020 project no. CZ.02.2.69/0.0/0.0/18_053/0017850 (Ministry of Education, Youth and Sports of the Czech Republic). U.S. was supported by CAB International with core financial support from its member countries (see http://www.cabi.org/about-cabi/who-we-work-with/key-donors/). A.P. and B.L. funded by ANID/Basal FB210006 and ANID NERC NE/S011641/1. J.L.R. received an Outside Studies Program (OSP) Fellowship from Macquarie University's Faculty of Science and Engineering that supported his contribution to this work. J. Pergl and M.V. acknowledge support from grant no. 23-05403K (Czech Science Foundation). J.R. acknowledges funding from the Spanish Ministry of Universities under application 33.50.460A.752 and the European Union NextGenerationEU/PRTR through a contract Margarita Salas of the Universidade de Vigo (UP2021-046). M.S.D. received financial support from CNPq (Research Productivity Scholarship-Bolsa de Produtividade em Pesquisa – # 302880/2022-4). M.V. acknowledges funding from grant no. GF23-05403K (Technology Agency of the Czech Republic) and long-term research development project RVO 67985939 (Czech Academy of Sciences). M.W. was funded by research core funding P4-0107 (Slovenian Research Agency). T.C. and T.S. were supported by the Italian Ministry of University and Research (project funded by the European Union-Next Generation EU: "PNRR Missione 4 Componente 2, "Dalla ricerca all'impresa", Investimento 1.4, Progetto CN00000033"). VL received financial support from the University of Sassari (Italy) and the Autonomous Region of Sardinia - Legge regionale 7 agosto 2007, n.7 "Promozione della Ricerca Scientifica e dell'Innovazione Tecnologica in Sardegna", "Mobilità Giovani Ricercatori (MGR)". The founder had no role in the study design, data collection and analysis, decision to publish or preparation of the manuscript. JRUW thanks the South African Department of Forestry, Fisheries, and the Environment (DFFE) for funding, noting that this publication does not necessarily represent the views or opinions of DFFE or its employees.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data available from the Dryad Digital Repository: https://doi.org/10.5061/dryad.2z34tmps3.

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REFERENCES

Aubin, I., Boisvert-Marsh, L., Kebli, H., McKenney, D., Pedlar, J., Lawrence, K., Hogg, E. H., Boulanger, Y., Gauthier, S., & Ste-Marie, C. (2018). Tree vulnerability to climate change: Improving exposure-based assessments using traits as indicators of sensitivity. *Ecosphere*, *9*(2), e02108. https://doi.org/10.1002/ecs2.2108

Bastin, J.-F., Finegold, Y., Garcia, C., Mollicone, D., Rezende, M., Routh, D., Zohner, C. M., & Crowther, T. W. (2019). The global tree restoration potential. *Science*, *365*(6448), 76–79. https://doi.org/10.1126/science.aax0848

Bindewald, A., Brundu, G., Schueler, S., Starfinger, U., Bauhus, J., & Lapin, K. (2021). Site-specific risk assessment enables trade-off analysis of non-native tree species in European forests. *Ecology and Evolution*, *11*(24), 18089–18110. https://doi.org/10.1002/ece3.8407

Brockerhoff, E. G., Jactel, H., Parrotta, J. A., Quine, C. P., & Sayer, J. (2008). Plantation forests and biodiversity: Oxymoron or opportunity? *Biodiversity and Conservation*, *17*(5), 925–951. https://doi.org/10.1007/s10531-008-9380-x

Brundu, G., Pauchard, A., Pyšek, P., Pergl, J., Bindewald, A. M., Brunori, A., Canavan, S., Campagnaro, T., Celesti-Grapow, L., De, M., Dechoum, S., Dufour-Dror, J.-M., Essl, F., Flory, S. L., Genovesi, P., Guarino, F., Guangzhe, L., Hulme, P. E., Jäger, H., … Richardson, D. M. (2020). Global guidelines for the sustainable use of non-native trees to prevent tree invasions and mitigate their negative impacts. *NeoBiota*, *61*, 65–116. https://doi.org/10.3897/neobiota.61.58380

Brundu, G., & Richardson, D. M. (2016). Planted forests and invasive alien trees in Europe: A code for managing existing and future plantings to mitigate the risk of negative impacts from invasions. *NeoBiota*, *30*, 5–47. https://doi.org/10.3897/neobiota.30.7015

Brus, R., Pötzelsberger, E., Lapin, K., Brundu, G., Orazio, C., Straigyte, L., & Hasenauer, H. (2019). Extent, distribution and origin of non-native forest tree species in Europe. *Scandinavian Journal of Forest Research*, *34*(7), 533–544. https://doi.org/10.1080/02827581.2019.1676464

Bryce, R., Oliver, M. K., Davies, L., Gray, H., Urquhart, J., & Lambin, X. (2011). Turning back the tide of American mink invasion at an unprecedented scale through community participation and adaptive management. *Biological Conservation*, *144*(1), 575–583. https://doi.org/10.1016/j.biocon.2010.10.013

Caires, N. P., Hermenegildo, P. S., Guimarães, L. M. S., Mafia, R. G., Zauza, E. Â. V., Júnior, N. B., Badel, J. L., & Alfenas, A. C. (2019). Host range of *Erwinia psidii* and genetic resistance of *Eucalyptus* and *Corymbia* species to this pathogen. *Forest Pathology*, *49*(4), e12527. https://doi.org/10.1111/efp.12527

Calviño-Cancela, M., & Rubido-Bará, M. (2013). Invasive potential of *Eucalyptus globulus*: Seed dispersal, seedling recruitment and survival in habitats surrounding plantations. *Forest Ecology and Management*, *305*, 129–137. https://doi.org/10.1016/j.foreco.2013.05.037

Castro-Díez, P., Vaz, A. S., Silva, J. S., Loo, M., Alonso, Á., Aponte, C., Bayón, Á., Bellingham, P. J., Chiuffo, M. C., DiManno, N., Julian, K., Kandert, S., La Porta, N., Marchante, H., Maule, H. G., Mayfield, M. M., Metcalfe, D., Monteverdi, M. C., Núñez, M. A., … Godoy, O. (2019). Global effects of non-native tree species on multiple ecosystem services. *Biological Reviews*, *94*(4), 1477–1501. https://doi.org/10.1111/brv.12511

Cubbage, F. W., Siry, J. P., & Abt, R. C. (2005). Fast-grown plantations, forest certification, and the U.S. South: Environmental benefits and economic sustainability. *New Zealand Journal of Forestry Science*, *35*, 266–289.

Dechoum, M. d. S., Giehl, E. L. H., Sühs, R. B., Silveira, T. C. L., & Ziller, S. R. (2019). Citizen engagement in the management of non-native invasive pines: Does it make a difference? *Biological Invasions*, *21*(1), 175–188. https://doi.org/10.1007/s10530-018-1814-0

Dehnen-Schmutz, K., Chas-Amil, M. L., & Touza, J. M. (2010). Stakeholders' perceptions of plant invasions in Galicia, Spain. *Aspects of Applied Biology*, *104*, 13–18.

Deus, E., Silva, J. S., Vicente, J. R., & Catry, F. X. (2022). Eucalypt recruitment and invasion potential in protected areas of the Iberian Peninsula under current and future climate conditions. *Forests*, *13*(8), 1199. https://doi.org/10.3390/f13081199

Dickie, I. A., Bennett, B. M., Burrows, L. E., Nuñez, M. A., Peltzer, D. A., Porté, A., Richardson, D. M., Rejmánek, M., Rundel, P. W., & van Wilgen, B. W. (2014). Conflicting values: Ecosystem services and invasive tree management. *Biological Invasions*, *16*(3), 705–719. https://doi.org/10.1007/s10530-013-0609-6

Doroski, D. A., Ashton, M. S., & Duguid, M. C. (2020). The future urban forest – A survey of tree planting programs in the Northeastern United States. *Urban Forestry & Urban Greening*, *55*, 126816. https://doi.org/10.1016/j.ufug.2020.126816

FAO. (2020). Global Forest Resources Assessment 2020. In *Global Forest Resources Assessment 2020*. FAO. https://doi.org/10.4060/ca8753en

Ford-Thompson, A. E. S., Snell, C., Saunders, G., & White, P. C. L. (2012). Stakeholder participation in management of invasive vertebrates. *Conservation Biology*, *26*(2), 345–356. https://doi.org/10.1111/j.1523-1739.2011.01819.x

FOREST EUROPE. (2020). *State of Europe's Forests* 2020.

Furr, R. M. (2011). *Scale construction and psychometrics for social and personality psychology*. SAGE Publications Ltd. https://doi.org/10.4135/9781446287866

García-Llorente, M., Martín-López, B., González, J. A., Alcorlo, P., & Montes, C. (2008). Social perceptions of the impacts and benefits of invasive alien species: Implications for management. *Biological Conservation*, *141*(12), 2969–2983. https://doi.org/10.1016/j.biocon.2008.09.003

Genovesi, P., & Shine, C. (2004). *European strategy on invasive alien species: Convention on the Conservation of European Wildlife and Habitats (Bern Convention)*.

Government of Canada. (2004). *An invasive alien species strategy for Canada* (p. 40). Environment Canada.

Haley, A. L., Lemieux, T. A., Piczak, M. L., Karau, S., D'Addario, A., Irvine, R. L., Beaudoin, C., Bennet, J. R., & Cooke, S. J. (2023). On the effectiveness of public awareness campaigns for the management of invasive species. *Environmental Conservation*, *50*(4), 202–211.

Hulme, P. E., Brundu, G., Carboni, M., Dehnen-Schmutz, K., Dullinger, S., Early, R., Essl, F., González-Moreno, P., Groom, Q. J., Kueffer, C., Kühn, I., Maurel, N., Novoa, A., Pergl, J., Pyšek, P., Seebens, H., Tanner, R., Touza, J. M., van Kleunen, M., & Verbrugge, L. N. H. (2018). Integrating invasive species policies across ornamental horticulture supply chains to prevent plant invasions. *Journal of Applied Ecology*, *55*(1), 92–98. https://doi.org/10.1111/1365-2664.12953

Hurley, B. P., Garnas, J., Wingfield, M. J., Branco, M., Richardson, D. M., & Slippers, B. (2016). Increasing numbers and intercontinental spread of invasive insects on eucalypts. *Biological Invasions*, *18*(4), 921–933. https://doi.org/10.1007/s10530-016-1081-x

Jarić, I., Courchamp, F., Correia, R. A., Crowley, S. L., Essl, F., Fischer, A., González-Moreno, P., Kalinkat, G., Lambin, X., Lenzner, B., Meinard, Y., Mill, A., Musseau, C., Novoa, A., Pergl, J., Pyšek, P., Pyšková, K., Robertson, P., von Schmalensee, M., … Jeschke, J. M. (2020). The role of species charisma in biological invasions. *Frontiers in Ecology and the Environment*, *18*(6), 345–353. https://doi.org/10.1002/fee.2195

Knight, D. H., Baker, W. L., Engelmark, O., & Nilsson, C. (2001). A landscape perspective on the establishment of exotic tree plantations: Lodgepole pine (*Pinus contorta*) in Sweden. *Forest Ecology and Management*, *141*(1–2), 131–142. https://doi.org/10.1016/S0378-1127(00)00496-5

Kowarik, I. (1995). Time lags in biological invasions with regard to the success and failure of alien species. In P. Pyšek, K. Prach, M. Rejmanek, & M. Wade (Eds.), *Plant invasions—General aspects and special problems* (pp. 15–38). SPB Academic Publishing.

Kull, C. A., Shackleton, C. M., Cunningham, P. J., Ducatillon, C., Dufour-Dror, J.-M., Esler, K. J., Friday, J. B., Gouveia, A. C., Griffin, A. R., Marchante, E., Midgley, S. J., Pauchard, A., Rangan, H., Richardson, D. M., Rinaudo, T., Tassin, J., Urgenson, L. S., von Maltitz, G. P., Zenni, R. D., & Zylstra, M. J. (2011). Adoption, use and perception of Australian acacias around the world. *Diversity and Distributions*, *17*(5), 822–836. https://doi.org/10.1111/j.1472-4642.2011.00783.x

Kull, C. A., & Tassin, J. (2012). Australian acacias: Useful and (sometimes) weedy. *Biological Invasions*, *14*(11), 2229–2233. https://doi.org/10.1007/s10530-012-0244-7

Low, T. (2012). Australian acacias: Weeds or useful trees? *Biological Invasions*, *14*(11), 2217–2227. https://doi.org/10.1007/s10530-012-0243-8

Lugo, A., Smith, J., Potter, K., Vega, H., & Kurtz, C. (2022). *Contribution of nonnative tree species to structure and composition of forests in the coterminous United States in comparison with tropical islands in the Pacific and Caribbean*.

Martin, M. P., Woodbury, D. J., Doroski, D. A., Nagele, E., Storace, M., Cook-Patton, S. C., Pasternack, R., & Ashton, M. S. (2021). People plant trees for utility more often than for biodiversity or carbon. *Biological Conservation*, *261*, 109224. https://doi.org/10.1016/j.biocon.2021.109224

Moran, V. C., Hoffmann, J. H., Donnelly, D., van Wilgen, B. W., & Zimmermann, H. (2000). Biological control of alien, invasive pine trees (*Pinus* species) in South Africa. In N. R. Spencer (Ed.), *Proceedings of the 5th International Symposium on Biological Control of Weeds* (pp. 941–953). Montana State University.

Nemoto, T., & Beglar, D. (2014). Likert-scale questionnaires. In N. Sonda & A. Krause (Eds.), *JALT 2013 Conference Proceedings* (pp. 1–8). Jalt.

Novoa, A., Kaplan, H., Wilson, J. R. U., & Richardson, D. M. (2016). Resolving a prickly situation: Involving stakeholders in invasive cactus management in South Africa. *Environmental Management*, *57*(5), 998–1008. https://doi.org/10.1007/s00267-015-0645-3

Novoa, A., Shackleton, R., Canavan, S., Cybèle, C., Davies, S. J., Dehnen-Schmutz, K., Fried, J., Gaertner, M., Geerts, S., Griffiths, C. L., Kaplan, H., Kumschick, S., Le Maitre, D. C., Measey, G. J., Nunes, A. L., Richardson, D. M., Robinson, T. B., Touza, J., & Wilson, J. R. U. (2018). A framework for engaging stakeholders on the management of alien species. *Journal of Environmental Management*, *205*, 286–297. https://doi.org/10.1016/j.jenvman.2017.09.059

Nuñez, M. A., Chiuffo, M. C., Torres, A., Paul, T., Dimarco, R. D., Raal, P., Policelli, N., Moyano, J., García, R. A., van Wilgen, B. W., Pauchard, A., & Richardson, D. M. (2017). Ecology and management of invasive Pinaceae around the world: Progress and challenges. *Biological Invasions*, *19*(11), 3099–3120. https://doi.org/10.1007/s10530-017-1483-4

Nygaard, P., & Øyen, B.-H. (2017). Spread of the introduced Sitka spruce (*Picea sitchensis*) in coastal Norway. *Forests*, *8*(1), 24. https://doi.org/10.3390/f8010024

Payn, T., Carnus, J.-M., Freer-Smith, P., Kimberley, M., Kollert, W., Liu, S., Orazio, C., Rodriguez, L., Silva, L. N., & Wingfield, M. J. (2015). Changes in planted forests and future global implications. *Forest Ecology and Management*, *352*, 57–67. https://doi.org/10.1016/j.foreco.2015.06.021

Pyšek, P., & Richardson, D. M. (2007). Traits associated with invasiveness in alien plants: Where do we stand? In *Biological Invasions* (pp. 97–125). Springer. https://doi.org/10.1007/978-3-540-36920-2_7

Queirós, L., Deus, E., Silva, J. S., Vicente, J., Ortiz, L., Fernandes, P. M., & Castro-Díez, P. (2020). Assessing the drivers and the recruitment potential of *Eucalyptus globulus* in the Iberian Peninsula. *Forest Ecology and Management*, *466*, 118147. https://doi.org/10.1016/j.foreco.2020.118147

Raiche, G., & Magis, D. (2022). *nFactors*: *Parallel analysis and other non graphical solutions to the Cattell scree test*. https://cran.r-project.org/web/packages/nFactors/nFactors.pdf

Reed, M. S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C. H., & Stringer, L. C. (2009). Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of Environmental Management*, *90*(5), 1933–1949. https://doi.org/10.1016/j.jenvman.2009.01.001

Revelle, W. (2019). *psych*: *Procedures for personality and psychological research*. https://cran.r-project.org/package=psychVersion=%0D1.9.12

Richardson, D. M., Hui, C., Nuñez, M. A., & Pauchard, A. (2014). Tree invasions: Patterns, processes, challenges and opportunities. *Biological Invasions*, *16*(3), 473–481. https://doi.org/10.1007/s10530-013-0606-9

Rosseel, Y. (2012). lavaan: An R package for structural equation modeling. *Journal of Statistical Software*, *48*(2). https://doi.org/10.18637/jss.v048.i02

Roy, H. E., Pauchard, A., Stoett, P., Renard Truong, T., Bacher, S., Galil, B. S., Hulme, P. E., Ikeda, T., Sankaran, K. V., McGeoch, M. A., Meyerson, L. A., Nuñez, M. A., Ordonez, A., Rahlao, S. J., Schwindt, E., Seebens, H., Sheppard, A. W., & Vandvik, V. (2023). *Summary for policymakers of the thematic assessment report on invasive alien species and their control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. IPBES Secretariat. https://doi.org/10.5281/zenodo.7430692

Rubilar, R., Hubbard, R., Emhart, V., Mardones, O., Quiroga, J. J., Medina, A., Valenzuela, H., Espinoza, J., Burgos, Y., & Bozo, D. (2020). Climate and water availability impacts on early growth and growth efficiency of Eucalyptus genotypes: The importance of GxE interactions. *Forest Ecology and Management*, *458*, 117763. https://doi.org/10.1016/j.foreco.2019.117763

Ruedin, D. (2020). *agrmt*: *Calculate concentration and dispersion in ordered rating scales*. R package version 1.42.4.

Sandbrook, C., Fisher, J. A., Holmes, G., Luque-Lora, R., & Keane, A. (2019). The global conservation movement is diverse but not divided. *Nature Sustainability*, *2*(4), 316–323. https://doi.org/10.1038/s41893-019-0267-5

Seidl, R., Klonner, G., Rammer, W., Essl, F., Moreno, A., Neumann, M., & Dullinger, S. (2018). Invasive alien pests threaten the carbon stored in Europe's forests. *Nature Communications*, *9*(1), 1626. https://doi.org/10.1038/s41467-018-04096-w

Shackleton, R. T., Adriaens, T., Brundu, G., Dehnen-Schmutz, K., Estévez, R. A., Fried, J., Larson, B. M. H., Liu, S., Marchante, E., Marchante, H., Moshobane, M. C., Novoa, A., Reed, M., & Richardson, D. M. (2019). Stakeholder engagement in the study and management of invasive alien species. *Journal of Environmental Management*, *229*, 88–101. https://doi.org/10.1016/j.jenvman.2018.04.044

Shackleton, R. T., Le Maitre, D. C., Pasiecznik, N. M., & Richardson, D. M. (2014). Prosopis: A global assessment of the biogeography, benefits, impacts and management of one of the world's worst woody invasive plant taxa. *AoB Plants*, *6*, plu027. https://doi.org/10.1093/aobpla/plu027

Shackleton, R. T., Richardson, D. M., Shackleton, C. M., Bennett, B., Crowley, S. L., Dehnen-Schmutz, K., Estévez, R. A., Fischer, A., Kueffer, C., Kull, C. A., Marchante, E., Novoa, A., Potgieter, L. J., Vaas, J., Vaz, A. S., & Larson, B. M. H. (2019). Explaining people's perceptions of invasive alien species: A conceptual framework. *Journal of Environmental Management*, *229*, 10–26. https://doi.org/10.1016/j.jenvman.2018.04.045

Sitzia, T., Campagnaro, T., Kowarik, I., & Trentanovi, G. (2016). Using forest management to control invasive alien species: Helping implement the new European regulation on invasive alien species. *Biological Invasions*, *18*(1), 1–7. https://doi.org/10.1007/s10530-015-0999-8

Smith, W., Mile, P., Vissage, J., & Pugh, S. (2004). *Forest resources of the United States*.

Touza, J., Pérez-Alonso, A., Chas-Amil, M. L., & Dehnen-Schmutz, K. (2014). Explaining the rank order of invasive plants by stakeholder groups. *Ecological Economics*, *105*, 330–341. https://doi.org/10.1016/j.ecolecon.2014.06.019

van Loo, M., Lazic, D., Chakraborty, D., Hasenauer, H., & Schüler, S. (2019). North American Douglas-fir (*P. menziesii*) in Europe: Establishment and reproduction within new geographic space without consequences for its genetic diversity. *Biological Invasions*, *21*(11), 3249–3267. https://doi.org/10.1007/s10530-019-02045-2

van Wilgen, B. W., & Richardson, D. M. (2014). Challenges and trade-offs in the management of invasive alien trees. *Biological Invasions*, *16*(3), 721–734. https://doi.org/10.1007/s10530-013-0615-8

Vaz, A. S., Honrado, J. P., & Lomba, A. (2019). Replacement of pine by eucalypt plantations: Effects on the diversity and structure of tree assemblages under land abandonment and implications for landscape management. *Landscape and Urban Planning*, *185*, 61–67. https://doi.org/10.1016/j.landurbplan.2019.01.009

Verbrugge, L., Leuven, R., van Valkenburg, J., & van den Born, R. (2014). Evaluating stakeholder awareness and involvement in risk prevention of aquatic invasive plant species by a national code of conduct. *Aquatic Invasions*, *9*(3), 369–381. https://doi.org/10.3391/ai.2014.9.3.11

Vítková, M., Müllerová, J., Sádlo, J., Pergl, J., & Pyšek, P. (2017). Black locust (*Robinia pseudoacacia*) beloved and despised: A story of an invasive tree in Central Europe. *Forest Ecology and Management*, *384*, 287–302. https://doi.org/10.1016/j.foreco.2016.10.057

Wood, L. E., Vimercati, G., Ferrini, S., & Shackleton, R. T. (2022). Perceptions of ecosystem services and disservices associated with open water swimming. *Journal of Outdoor Recreation and Tourism*, *37*, 100491. https://doi.org/10.1016/j.jort.2022.100491

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Section S1. Questionnaire on NNTS.

Figure S1. Plot showing the level of agreement between multiple eigenvalue-based methods computed to define the optimal number of factors to retain in an exploratory factor analysis conducted on half of the response database.

Table S1. Factor loadings from exploratory five-factor analysis.

Table S2. Goodness-of-fit indexes obtained through a confirmatory four-factor analysis performed on the half of the response database.

How to cite this article: Novoa, A., Vimercati, G., Brundu, G., Richardson, D. M., Schaffner, U., Brunori, A., Campagnaro, T., Canavan, S., Celesti-Grapow, L., Dechoum, M., Dehnen-Schmutz, K., Dufour-Dror, J.-M., Essl, F., Flory, S. L., Jäger, H., Joshi, J., Karmann, M., Langdon, B., Lapin, K., … Wilson, J. R. U. (2024). Stakeholders' views on the global guidelines for the sustainable use of non-native trees. *People and Nature*, *00*, 1–15. https://doi.org/10.1002/pan3.10670