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Global guidelines for the sustainable use of non-native trees to prevent tree invasions and mitigate their negative impacts

Giuseppe Brundu[1], Aníbal Pauchard[2,3], Petr Pyšek[4,5], Jan Pergl[4], Anja M. Bindewald[6,7], Antonio Brunori[8], Susan Canavan[9], Thomas Campagnaro[10], Laura Celesti-Grapow[11], Michele de Sá Dechoum[12], Jean-Marc Dufour-Dror[13], Franz Essl[14], S. Luke Flory[9], Piero Genovesi[15,16], Francesco Guarino[17], Liu Guangzhe[18], Philip E. Hulme[19], Heinke Jäger[20], Christopher J. Kettle[21,22], Frank Krumm[23], Bárbara Langdon[2,3], Katharina Lapin[24], Vanessa Lozano[1], Johannes J. Le Roux[25], Ana Novoa[4], Martin A. Nuñez[26], Annabel J. Porté[27], Joaquim S. Silva[28,29], Urs Schaffner[30], Tommaso Sitzia[10], Rob Tanner[31], Ntakadzeni Tshidada[32], Michaela Vítková[4], Marjana Westergren[33], John R.U. Wilson[34,35], David M. Richardson[35]

1 *Department of Agriculture, University of Sassari, Viale Italia 39, 07100, Sassari, Italy* **2** *Facultad de Ciencias Forestales, Universidad de Concepción, Concepción, Chile* **3** *Institute of Ecology and Biodiversity, Santiago, Chile* **4** *Czech Academy of Sciences, Institute of Botany, Department of Invasion Ecology, CZ-252 43, Průhonice, Czech Republic* **5** *Department of Ecology, Faculty of Science, Charles University, Viničná 7, CZ-128 44, Prague 2, Czech Republic* **6** *Department of Forest Conservation, Forest Research Institute of Baden-Württemberg (FVA), Freiburg 79100, Germany* **7** *Chair of Silviculture, University of Freiburg, Freiburg 79085, Germany* **8** *PEFC, Perugia, Italy* **9** *Agronomy Department, University of Florida, 32611, Gainesville, FL, USA* **10** *Department of Land, Environment, Agriculture and Forestry, Università degli Studi di Padova, Viale dell'Università 16, 35020, Legnaro, PD, Italy* **11** *Department of Environmental Biology, Sapienza University, Piazzale A. Moro 5, 00185, Rome, Italy* **12** *Departamento de Ecologia e Zoologia, Programa de Pós-graduação em Ecologia, Universidade Federal de Santa Catarina, Campus Universitário, CEP 88040-900, Florianopolis, SC, Brazil* **13** *Independent Ecologist, Consultant, Shachar st. 1, Jerusalem 9626301, Israel* **14** *BioInvasions, Global Change, Macroecology-Group, Division of Conservation Biology, Vegetation Ecology and Landscape Ecology, Department of Botany and Biodiversity Research, University Vienna, Rennweg 14, 1030, Vienna* **15** *Institute for Environmental Protection and Research (ISPRA), Via V. Brancati 48 – 00144, Rome, Italy* **16** *Chair IUCN SSC Invasive Species Specialist Group, Rome, Italy* **17** *Department of Chemistry and Biology "A. Zambelli", University of Salerno, via Giovanni Paolo II, 132 84084, Fisciano (SA), Italy* **18** *College of Forestry, Northwest A&F University, 3 Taicheng Rd., Yangling, Shaanxi 712100, China* **19** *The Bio-Protection Research Centre, Lincoln University, PO Box 85084, Christchurch, New Zealand* **20** *Charles Darwin Research Station, Charles Darwin Foundation, Santa Cruz, Galapagos, Ecuador* **21** *Department of Environmental System Science ETH Zurich, Switzerland* **22** *Bioversity International, Rome, Italy* **23** *Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zürcherstrasse 111, CH-8903, Birmensdorf, Switzerland* **24** *Austrian Federal Research Centre for Forests, Natural Hazards and*

Landscape (BFW), Seckendorff-Gudent-Weg 8, 1131, Vienna, Austria **25** *Department of Biological Sciences, Macquarie University, Sydney, Australia* **26** *Grupo de Ecologia de Invasiones, INIBIOMA, CONICET, Univ. Nacional del Comahue, San Carlos de Bariloche, Argentina* **27** *Université de Bordeaux, INRAE, BIOGECO, F-33615, Pessac, France* **28** *College of Agriculture, Polytechnic of Coimbra, 3045-601, Coimbra, Portugal* **29** *Centre for Functional Ecology, University of Coimbra, 3000-456, Coimbra, Portugal* **30** *CABI, CH-2800, Delémont, Switzerland* **31** *European and Mediterranean Plant Protection Organization, Paris, France* **32** *Department of Environment, Forestry and Fisheries, Pretoria, South Africa* **33** *Slovenian Forestry Institute, Ljubljana, Slovenia* **34** *South African National Biodiversity Institute, Kirstenbosch Research Centre, Cape Town, South Africa* **35** *Centre for Invasion Biology, Department of Botany and Zoology, Stellenbosch University, Stellenbosch, South Africa*

Corresponding author: Giuseppe Brundu (gbrundu@uniss.it)

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Abstract

Sustainably managed non-native trees deliver economic and societal benefits with limited risk of spread to adjoining areas. However, some plantations have launched invasions that cause substantial damage to biodiversity and ecosystem services, while others pose substantial threats of causing such impacts. The challenge is to maximise the benefits of non-native trees, while minimising negative impacts and preserving future benefits and options.

A workshop was held in 2019 to develop global guidelines for the sustainable use of non-native trees, using the Council of Europe – Bern Convention Code of Conduct on Invasive Alien Trees as a starting point.

The global guidelines consist of eight recommendations: 1) Use native trees, or non-invasive non-native trees, in preference to invasive non-native trees; 2) Be aware of and comply with international, national, and regional regulations concerning non-native trees; 3) Be aware of the risk of invasion and consider global change trends; 4) Design and adopt tailored practices for plantation site selection and silvicultural management; 5) Promote and implement early detection and rapid response programmes; 6) Design and adopt tailored practices for invasive non-native tree control, habitat restoration, and for dealing with highly modified ecosystems; 7) Engage with stakeholders on the risks posed by invasive non-native trees, the impacts caused, and the options for management; and 8) Develop and support global networks, collaborative research, and information sharing on native and non-native trees.

The global guidelines are a first step towards building global consensus on the precautions that should be taken when introducing and planting non-native trees. They are voluntary and are intended to complement statutory requirements under international and national legislation. The application of the global guidelines and the achievement of their goals will help to conserve forest biodiversity, ensure sustainable forestry, and contribute to the achievement of several Sustainable Development Goals of the United Nations linked with forest biodiversity.

Keywords
Biological invasions, code of conduct, environmental policy and legislation, invasion science, stakeholder engagement, stakeholder participation, sustainable forestry, tree invasions

Introduction

Non-native trees (hereafter NNTs) and sustainably managed plantation forests of NNTs provide a wide range of forest goods and services and help to reduce the pressure on natural forests (FAO 2010a, b). Because of their often greater hardiness, faster growth rates, and resistance to climate change, pathogens, and pests compared to native species (Bolte et al. 2009; Seidl et al. 2017), the standardisation of silviculture techniques (e.g., nurseries, seedling establishment, and thinning), and industrial processes for their products (e.g., timber and pulp), certain NNTs are favoured over native species in tree planting programmes (Wang et al. 2013; Papaioannou et al. 2016; Brus et al. 2019; Vítková et al. 2020). As a result, NNTs make up 44 percent of plantation forests globally (approximately 58 million ha) (FAO 2020). The prevalence of NNT forestry plantings varies significantly between regions. For example, plantation forests in North and Central America mostly comprise native species whereas those in South America consist almost entirely of NNTs (FAO 2020).

This large extent of NNTs is, in part, due to the rapid decrease in the extent of natural forests. Many on-going large-scale planting initiatives, sometimes with NNTs, aim to compensate for the loss of natural forests. Some examples of drivers of this loss are the reduction of natural forests caused by human activities in tropical regions of Brazil (Seymour and Harris 2019; Klug et al. 2020), in Chile (Braun et al. 2017), and in cold regions of Russia (e.g., Trunov 2017), and the loss of conifer forests in North America and Europe due to recent bark-beetle outbreaks (Morris et al. 2017; Hlásny et al. 2019). The expansion of NNT plantations has been highlighted as a major land use/cover change worldwide, leading both to deforestation and loss of agricultural land (Hua et al. 2016; Benra et al. 2019), although this varies by country and depends on underlying policies and economic situations (Pirard et al. 2017).

NNTs also represent a significant component of urban forests and are widely planted in urban greening projects worldwide (Bauduceau et al. 2015; Sjöman et al. 2016; Castro-Díez et al. 2019; Escobedo et al. 2019). The continuous growth in urban populations creates demands and opportunities for urban forests to deliver ecosystem services critical to human wellbeing and biodiversity (dos Santos et al. 2010; Potgieter et al. 2017; Endreny 2018; Riley et al. 2018; Kowarik et al. 2019). NNTs are often promoted in cities because of their aesthetic value, easy and well-known requirements for maintenance, higher growth rate than native species, and the reliability of achieving greening and the associated ecosystem and social services (Dickie et al. 2014; Potgieter et al. 2017).

Botanic gardens and arboreta, all hosting a large variety of NNTs, are increasingly recognised as key components of global plant conservation efforts through their living collections of endangered species, long-term archiving of seeds, taxonomic training, and public outreach (Hulme 2011). Yet, an increasing body of evidence highlights the role of botanic gardens in facilitating plant invasions worldwide (Hanspach et al. 2008; Hulme 2011, 2015; van Kleunen et al. 2018), albeit at a much smaller scale than through commercial horticulture and forestry practices. A number of botanic gardens now apply stringent measures to prevent the spread of invasive species and to promote the use of native species in ecological restoration efforts, but most do not (Hulme 2015).

A major change in the planting of trees has emerged recently, as massive tree-planting campaigns using NNTs are beginning to gain momentum globally as an assumed silver bullet to mitigate the impacts of climate change and for other purposes such as poverty alleviation (Table 1). In response to climate change, trees, regardless of their biogeographical status (native or non-native), are being presented as a general panacea (Bastin et al. 2019). However, emerging research suggests that trees might not help offset carbon emissions as much as some would expect (e.g., Popkin 2019), and plantations in inappropriate sites can have disastrous consequences for sustainable development, biodiversity conservation, and ecosystem functioning (Bond 2016; Bond et al. 2019; Temperton et al. 2019), and even may lead to a loss of soil organic carbon (Jackson et al. 2002). Silveira et al. (2020) highlighted the myth that tree planting is always good for biodiversity and ecosystem services and that the use of trees in the restoration of tropical and subtropical old-growth grassy biomes is misguided. The notion that the presence of trees indicates good ecosystem health is a driver of tree planting initiatives (Table 1) in many parts of the world (Richardson et al. 2014). In many cases, increased tree cover is clearly at odds with objectives of biodiversity conservation and the sustained delivery of ecosystem services (e.g., Jackson et al. 2005).

Although sustainably managed NNTs can and do deliver economic and societal benefits with limited risk of escape and spread from planting sites into adjoining areas in many contexts, some widely used NNTs are invasive or have high potential to become invasive, sometimes causing substantial damage to biodiversity and related ecosystem services and functioning (Richardson 1998; Richardson et al. 2000; Richardson and Rejmánek 2011; Castro-Díez et al. 2019). Many of the traits that are desired in NNTs are the same as those that have been recognised as promoting invasiveness (e.g., fast growth rate, high seed production, and high seedling survival) (Pyšek and Richardson 2007). The number of NNTs that are being reported as spreading and causing negative effects on biodiversity and ecosystem services is increasing rapidly globally (Rejmánek and Richardson 2013; Krumm and Vítková 2016).

Invasive NNTs (INNTs) can be important ecosystem engineers, i.e. they "directly or indirectly modulate the availability of resources to other species by causing physical state changes by biotic or abiotic materials" (Jones et al. 1994; Mitchell et al. 2007; Ayanu et al. 2015). They can also cause regime shifts in invaded ecosystems (altered states of ecosystem structure and function that are difficult or impossible to reverse), alter the identity of dominant species and therefore change dynamics on all levels, leading to impacts that ripple across trophic levels such as in the case of ecosystems invaded by *Acacia cyclops*, *A. longifolia*, and *A. saligna* (Gaertner et al. 2014; Souza-Alonso et al. 2017) or by *Tamarix* sp.pl. affecting the flood and sediment regime (Zavaleta 2000). INNTs can also radically change fire regimes by increasing fuel availability and flammability (Paritsis et al. 2018; Davis et al. 2019), which can have disastrous effects on ecosystems and people (e.g., in Chile, Portugal, South Africa, and Spain). The impacts of such invasions are particularly notable in naturally treeless ecosystems (Jäger et al. 2007; Rundel et al. 2014). Moreover, the spread of INNTs are among the invasions with the greatest impacts on ecosystem services such as water provision (Richardson 1998; Le Maitre et al. 2002; van Wilgen and Richardson 2012; Richardson et al. 2014).

As for many other groups of non-native species, perceptions regarding NNTs differ across interest groups, sometimes creating conflicts around their use and management (Starfinger et al. 2003; van Wilgen and Richardson 2014; Woodford et al. 2016; Vítková et al. 2017). For example, among some of the most widely planted genera such as *Acacia* s.l., *Eucalyptus* s.l., and *Pinus* there are many invasive species that have severe impacts on biodiversity and ecosystem services (Richardson 2011; Richardson and Rejmánek 2011; Cazetta and Zenni 2020). *Prosopis* species were introduced by NGOs and government organisations to countries like Kenya in the 1970s and 1980s to provide wood and animal fodder, and to stabilise soils in degraded ecosystems (Swallow and Mwangi 2008; Maundu et al. 2009). There is continuing advocacy for the utilisation of these NNTs (Choge et al. 2007), despite clear evidence that these species have devasting effects on human livelihoods and biodiversity (e.g., Mbaabu et al. 2019; Linders et al. 2019). Kenya is, as far as we know, the only country that has enshrined in its constitution the goal of achieving a particular level of national tree cover (10%). According to the corresponding National Strategy, the achievement of this goal will require the planting of NNTs, including INNTs which are among the worst invasive species worldwide. This is particularly troublesome in the case of *Prosopis juliflora*: while the area covered by this notoriously INNT is included in Kenya's estimates of current tree cover, the country has recently also launched a National Prosopis Strategy which aims to bring the invasion of this species under control in order to protect Kenya's nature, people, and the economy (http://www.environment.go.ke/).

The challenge is to maximise the socio-economic benefits and opportunities of NNTs, while minimising risks and negative impacts on the environment or compromising future benefits and land uses (Richardson 2011; Brundu and Richardson 2016). Addressing this challenge requires collaborations between governments, non-governmental organisations, environmental managers, forestry and horticultural industries, and other parties to develop and promote tailored policies, coordinate existing legislation tools, ensure capacity building, promote the preferential use of native trees, ensure the responsible introduction and sustainable use of NNTs globally, and to identify and share best-management practices to deal with INNTs. Such measures are essential to mitigate and reduce the negative impacts from unregulated and poorly informed use and dissemination of NNTs. To increase the awareness of issues associated with the use of NNTs and the potential risks, this paper proposes a set of

Table 1. Examples of massive tree planting campaigns.

Name of the initiative	Geographical scope	Aim of the initiative, tree species considered	Web site / Reference
The Great Green Wall initiative (African Union)	Africa (the Sahel)	Restore degraded land, sequester carbon and create green jobs by 2030 to reduce desertification; no indication for species used.	http://www.unccd.int/actions/great-green-wall-initiative (Bond et al. 2019) http://time.com/5669033/great-green-wall-africa
The Trillion Trees campaign (NGO)	Global	Plant and protect one trillion trees to mitigate climate change and promote prosperity by 2050; native tree species are preferred, but planting NNTs is considered when there is a clear socio-economic, ecological, or climatic reason.	http://www.trilliontrees.org/home (Cernansky 2018)
Tree Nation (NGO)	Global	Citizens and companies can compensate CO_2 emissions by supporting tree planting projects worldwide; trees are being chosen of a list of 300 species, but without further information if native trees are preferred over NNTs.	http://tree-nation.com
Plant for the Planet (NGO)	Global	Platform enables to support tree planting projects worldwide with the goal to plant 1.000 billion trees; no indication for species used.	http://www.plant-for-the-planet.org/en/home http://www.unenvironment.org/news-and-stories/press-release/planting-trees-has-never-been-easier
The Bonn Challenge (launched by German) Government)	Global	Restore 150 million hectares of deforested and degraded land by 2020 and 350 million hectares by 2030 worldwide; no indication for species used.	http://www.bonnchallenge.org
The "Seed Bombing" initiative (Thai Government)	Thailand	Reforestation programme in Thailand throwing "seed bombs" from planes; only native species are considered.	http://thelondonpost.net/tree-seeds-tree-seeds-bombing-thailand
The Billion Tree Tsunami Afforestation Project (BTTAP) (Khyber Pakhtunkhwa Government)	Pakistan	The BTTAP in Pakistan's northern Khyber Pakhtunkhwa province was launched in 2015. It has surpassed its target by restoring and planting trees in 350,000 hectares of degraded forest landscapes; no indication for species used.	http://ejatlas.org/conflict/billion-tree-tsunami-afforestation-project (Nazir et al. 2019)
The Billion Trees campaign (NGO)	Global	Afforestation campaign with the goal to plant a billion trees across the planet to mitigate climate change; no indication for species used.	http://www.nature.org/en-us/get-involved/how-to-help/plant-a-billion http://www.unenvironment.org/resources/publication/plant-planet-billion-tree-campaign
The One Billion Trees Programme (New Zealand Government)	New Zealand	Afforestation and reforestation programme with the aim to plant one billion trees to diversify existing land uses across New Zealand and to improve socio-economic performance; planting native species is encouraged to improve biodiversity.	http://www.mpi.govt.nz/funding-and-programmes/forestry/one-billion-trees-programme/about-the-one-billion-trees-programme/
The Three-North Shelter Forest Program (Chinese Government)	China	More than 66 billion trees were planted since 1978 to stop expansion of arid regions; NNTs and native species have been used so far, but native vegetation will be preferred in future.	http://www.nature.com/articles/d41586-019-02789-w http://news.bbc.co.uk/2/hi/world/monitoring/media_reports/1199218.stm (Ge et al. 2020)
The 300,000 Trees in Nicosia initiative (Cyprus Government)	Cyprus	Afforestation programme with the aim to plant about 50,000 trees to combat climate change and protect biodiversity; planting indigenous species, such as endemic and rare varieties, is encouraged.	http://www.themayor.eu/fr/nicosia-launches-large-scale-tree-planting-campaign
The 60 Million Trees initiative (Madagascar Government)	Madagascar	Reforestation project with the aim to plant 60 Million trees across 40,000 hectares; endemic and agroforestry species, including NNTs and INNTs, are being used to balance economic and ecological interests.	http://www.ecowatch.com/madacascar-tree-planting-2644879937.html
The 50 Million For Our Forests campaign (NGO)	USA	Reforestation campaign with the aim to plant about 50 million trees to combat forest loss due to natural disturbances; only native trees are being used.	http://www.nationalforests.org/get-involved/tree-planting-programs
The 73 Million Trees in the Amazon initiative (NGO)	Brazil	Reforestation programme with the aim to plant 73 million trees in the Amazon rainforest to combat forest loss; only native tree species are being used.	http://www.smithsonianmag.com/smart-news/brazil-begins-effort-plant-73-million-trees-amazon-180967086/
The 350 million trees in 12 hours Guinness record (Ethiopia Government)	Ethiopia	Afforestation project with the aim to plant 4 billion trees to combat deforestation and climate change effects; 350 million trees were planted in 12 hours setting a new world record; no indication for species used.	http://albertonrecord.co.za/221373/afforestation-project-ethiopia-recently-resulted-350-million-trees-planted-one-day/

Name of the initiative	Geographical scope	Aim of the initiative, tree species considered	Web site / Reference
Conversion of Cropland to Forest Program (also called Grain for Green) (Chinese government)	China	Tree-planting enterprise (since 1999) that pays farmers to plant trees on their land and provides degraded land to rural families to restore; native and NNTs are being used.	http://forestsnews.cifor.org/52964/grain-for-green-how-china-is-swapping-farmland-for-forest?fnl=en http://www.cifor.org/publications/pdf_files/articles/APutzel1601.pdf (TheOneEartheditorial team 2020)
Millennium show forest (Chinese government)	China (new city "Xiongang New Area")	Massive urban afforestation project to construct a close-to-natural urban forest with the aim to minimise invasive species impacts; prioritisation of local species and seedlings.	(Li et al. 2020)
Eden Reforestation Programme (NGO)	Global	Reforestation project with the aim to reduce poverty and restore forests by hiring local villagers to plant trees; no indication for species used.	http://edenprojects.org
WeForest Making Earth Cooler (NGO)	Global	Forest and landscape restoration programme with the aim to mitigate climate change, conserve biodiversity, and reduce poverty of local communities; no indication for species used.	http://weforest.org
OneTreePlanted (NGO)	Global	Reforestation programme to protect biodiversity, restore degraded soils, improve climate, and reduce poverty; no indication for species used.	http://onetreeplanted.org
60 Million trees (60 Milioni di Alberi)	Italy	Planting one tree for each Italian citizen to fight climate change. It is recommended the use of native or non-native non-invasive trees.	http://www.alberitalia.it

Global Guidelines for the use of Non-Native Trees (GG-NNTs). These GG-NNTs were developed, discussed, and elaborated at a workshop in Prague, Czech Republic, in September 2019 that was attended by many of the co-authors of this paper. The guidelines and supporting text were further developed in consultation with a large number of researchers and other interested and affected parties in the fields of arboriculture, forestry, nature conservation, and invasion science. In compiling the working team, consideration was given to geographic and gender balance and diversity of age and expertise. However, we recognize that certain areas, especially in low and lower-middle income countries, are underrepresented and should be considered in future efforts.

Global Guidelines for the use of Non-Native Trees (GG-NNTs)

The GG-NNTs set out in this paper are addressed to all relevant stakeholders (including policy makers, the forestry and agroforestry industries, national forest authorities, certification bodies, environmental organisations, organisations and individuals involved in urban greening, landscape architecture, climate change mitigation, and all other endeavours that rely on the planting and management of trees). The GG-NNTs aim to reduce the risk of introduction of new INNTs and the negative impacts that might originate from their unregulated and/or unscrupulous use. To do so, these guidelines aim to enlist the co-operation of all relevant stakeholders to identify both robust scientific knowledge and technical knowledge and experience regarding the use and management of NNTs. Containment of NNTs to areas set aside for their cultivation or use must become an integral part of silviculture. Managers and planners need to consider the species and the environmental context and therefore should develop a stratified approach to take into account regional and habitat-specific management (van Wilgen and Richardson 2012; Pergl et al. 2016; Sádlo et al. 2017; Campagnaro et al. 2018).

The eight recommendations (Rec.) in the GG-NNTs are clustered according to three overarching goals (Fig. 1): (1) preventing the introduction of INNTs; (2) preventing and mitigating the risk of escape of NNTs from plantation sites to adjoining areas; and (3) mitigating the negative impacts of INNTs. They are not an exhaustive list of recommendations, but rather provide the first step towards building a global consensus on the precautions that should be taken when introducing and planting NNTs, particularly over large areas. The GG-NNTs are voluntary, and are intended to complement and guide statutory requirements under international or national legislation. Private forestry enterprises, local authorities, arboreta, and public forest managers might wish to publicise their adherence to the GG-NNTs through adopting a symbol or logo indicating this commitment (Fig. 2). The GG-NNTs could be incorporated in national or regional strategic documents or plans dealing with non-native species.

The GG-NNTs aim to implement and expand the geographical context of most of the principles and recommendations of the European Code of Conduct for Invasive Alien Trees as endorsed by The Standing Committee to the Convention on the Conservation of European Wildlife and Natural Habitats, acting under the terms of article 14 of the Bern Convention, on the 8^{th} of December 2017 (Rec. No. 193/2017). The Bern Convention has endorsed two other Codes that included overlapping principles addressing NNTs used as ornamental species, i.e. the Code of Conduct on Horticulture and Invasive Alien Plants published by the Council of Europe (Heywood and Brunel 2011) or kept in botanic garden and arboreta (European Code of Conduct for Botanic Gardens on Invasive Alien Species, Heywood and Sharrock 2013). Therefore, in proposing the GG-NNTs we mainly focus on NNTs used in forestry, in other types of large-scale plantings, restoration projects, and in urban forestry.

Terminology and structure of the GG-NNTs and their recommendations

In the context of the present GG-NNTs, and in accordance with the Convention on Biological Diversity (CBD) principles and definitions (Decision V/8 of the Conference of the Parties to the CBD), the term non-native trees (NNTs) has exclusively a biogeographical meaning, i.e. it refers to tree species, subspecies, lower taxa, or genotypes, introduced through human activity outside their past or present natural distributions, and includes any part, seeds or propagules of such taxa that might survive and subsequently reproduce. As such, the term NNTs carries no *a priori* connotation (negative or positive) relating to risks to biodiversity (or to the economy or public health). For a detailed discussion of the terms used in these GG-NNTs and how they relate to those used internationally see Annex 1, Glossary/Acronyms.

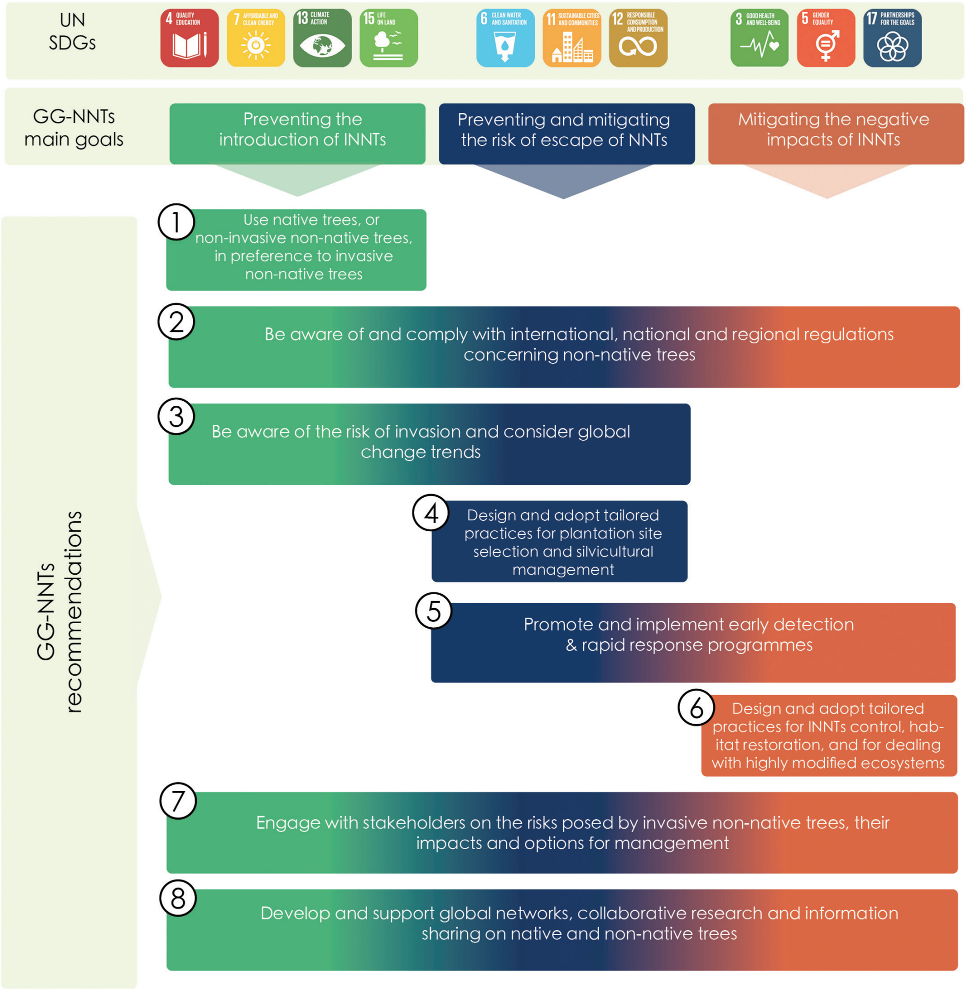

Figure 1. Main goals and recommendations of the Global Guidelines for the use of Non-Native Trees (GG-NNTs) in relation to the Sustainable Development Goals of the United Nations (UN SDGs).

In the context of the GG-NNTs, the terms alien, allochthonous, non-native, non-indigenous, exotic, and introduced are considered synonymous. These synonyms are all used in international and national legislation and in various technical documents, although with different frequency and with sometimes subtle differences in the meaning they convey. Therefore, for consistency, we use the term NNTs in accordance with the CBD definition, and for the purposes of the GG-NNTs, the term invasive non-native trees (or INNTs) is herewith defined as a NNTs whose introduction and/or spread threatens or adversely impacts biodiversity and related ecosystem services, or causes ecosystem disservices (Vaz et al. 2017), recognising that negative impacts on the economy and on public health might occur as well (Bacher et al. 2018).

GG-NNTs

Preventing and mitigating
the impacts
of tree invasions

Figure 2. Private forestry enterprises, local authorities, arboreta and public forest managers might wish to publicise their adherence to the GG-NNTs through adopting a symbol or logo indicating this commitment.

Recommendation 1: Use native trees, or non-invasive non-native trees, in preference to invasive non-native trees

Native tree species should be preferred over NNTs, and consideration should be given to the precise provenance of seeds and germplasm. If native tree species are not suitable, the consequent recommendation is to evaluate the use of NNTs with low invasion risk.

Within a country or region, native tree species rather than NNTs, should be used, in planning and establishing large-scale plantings, afforestation or reforestation projects, planted forest, and agroforestry (Douglas et al. 2014; Peltzer et al. 2015) wherever possible. This approach is particularly important in massive and global projects such as the Trillion Trees campaign, the African Green Wall initiative (Goffner et al. 2019), the China's Grain-for-Green Program (Hua et al. 2016), and the Bonn Challenge (Temperton et al. 2019) (Table 1).

Multiple organisations have suggested, under certain conditions, the promotion of native trees over NNTs, including, for example, FAO (FAO 2006; FAO 2010 – Principle 9 – "if native trees are equal to or better than introduced species for the intended purpose") and UNFCC (Aarrestad et al. 2014). FSC certification comprises 10 principles and 70 criteria that cover environmental, social, and economic aspects of forest management. The FSC standard uses the CBD definition of alien species and criterion 10.3 (Principle 10 "Implementation of Management Activities") states that "The Organisation shall only use alien species when knowledge and/or experience have shown that any invasive impacts can be controlled and effective mitigation measures are in place". Before introducing NNTs, FSC certification requires the presence of a management plan and scientific evaluations (Indicator 10.3.1), a stakeholder consultation and the use of effective mitigation measures to avoid the spread of NNTs outside the management unit area (Indicator 10.3.2), and the cooperation with competent authorities/bodies (Indicator 10.3.3).

PEFC certification system sets international Sustainable Forest Management benchmarks (see PEFC ST 1003:2018, Sustainable Forest Management – Requirements); within the framework provided by these benchmarks (11 criteria and 48 guidelines), national stakeholders develop their own national standards with the open participation of interested parties in a consensus-driven decision making process. All 54 recognised national standards require that origins of native species that are well-adapted to site conditions shall be preferred for reforestation and afforestation. Only those NNT species, provenances or varieties shall be used whose impacts on the ecosystem and on the genetic integrity of native species and local provenances have been scientifically evaluated, and if negative impacts can be avoided or minimised (Stupak et al. 2011). PEFC national standards recognise as guidance for avoidance of non-native invasive species CBD Guiding Principles for the Prevention, Introduction, and Mitigation of Impacts of Alien Species that Threaten Ecosystems, Habitats or Species.

Native tree species exhibit multiple local adaptations to the climate of their habitat, guaranteeing optimal growth and survival under stable environmental conditions (Aitken et al. 2008). For example, in the hot arid North African desert belt, the conservation of stands of the native *Vachellia tortilis* subsp. *raddiana* and augmentative restoration plantings of seeds or seedlings may promote invasion resistance through establishment of shade to limit the invasion of *Prosopis glandulosa* (Abbas et al. 2019). The seedlings of *V. tortilis* subsp. *raddiana* are able to implement important shifts in key functional traits in response to altering abiotic stress conditions, behaving as a stress-tolerant species that is well-adapted to the habitat it occupies in the hot arid deserts of North Africa.

With global change, the link between climate and local adaptation may be disrupted, leading to local provenances of native tree species no longer providing the required ecosystem services (Alfaro et al. 2014; Podrázský et al. 2020). Different provenances of tree species with wide natural distribution ranges are adapted to different conditions. Thus, a possible match for a planting site in terms of vitality and productivity should first be sought among provenances of already present native tree species, drawing from the vast network of provenance trials and models built upon them. In a second step, provenances of other native species that are predicted to be better adapted to the planting site should be considered. Only if both alternatives have been exhausted, should NNTs be considered for planting to sustain the required ecosystem services (Bolte et al. 2009; Allen et al. 2010; Brus et al. 2018; Frischbier et al. 2019). According to Climate-Smart Forestry (CSF), an emerging branch of sustainable forest management, one option to further resilience and adaptability of native forest diversity is to improve connectivity and migration corridors of key species and forest structures to sustain the availability of seed sources, as well as genetic variation (Bowditch et al. 2020).

When native tree species cannot be used, it is necessary to evaluate the use of NNTs with an expected low risk of invasiveness. Standard weed risk assessment tools can be successful at distinguishing between INNTs and non-invasive NNTs; see Gordon et al. (2012), and Ziller et al. (2019) for *Eucalyptus*, and McGregor et al. (2012) for pines. New data and information on the biology and ecology of species may result in a change of the risk assessment and evaluation outcomes. However, the use of weed risk assessment tools might not be familiar to practitioners and risk assessment and management approaches should be carefully communicated among relevant stakeholders (Stokes et al. 2006). Lorentz and Minogue (2015) remarked that trait selection during breeding is potentially a very effective containment approach for managing the risk of invasiveness in non-native *Eucalyptus* taxa. The likelihood of spread can be reduced by decreasing fecundity or by increasing the age to maturity, although the latter method may negatively influence productivity (Gordon et al. 2012). This strategy has been successfully implemented in other taxonomic groups, including a triploid *Leucaena* hybrid in Hawaii (Richardson 1998). Likewise, elimination of seed production is considered a feasible goal for *Eucalyptus* (Gordon et al. 2012), and elimination of fertile pollen production has been accomplished in the transgenic hybrid *E. grandis* × *E. urophylla* (AGEH427) (Hinchee et al. 2011). There have been some suggestions that polyploidy may be related with invasiveness of forestry species, as in the case of *Prosopis juliflora* (Kaur et al. 2012). Polyploids may have an advantage over their diploid progenitors in having higher growth vigour but are often sterile (Pandit et al. 2011). In the case of *Robinia pseudoacacia*, there are many cultigens that are generally less invasive than the typical form (Sádlo et al. 2017). For some species of Pinaceae, there is a good understanding of the invasiveness of the different species, with some species having low invasion risk (Rejmánek 1996; Carrillo-Gavilán and Vilà 2010; McGregor et al. 2012). This understanding has been used in some areas to promote plantations with fewer invasive species and to discourage the plantation of highly invasive species (Nuñez et al. 2017). However, a careful assessment and evaluation of risk and benefits is always necessary. For example, male individuals of non-native *Populus* clones suitable for fast growing bioenergy plantations might be recommended to prevent seed dispersal to natural areas, but it is important to locate the site so as to avoid the risk of hybridisation with native poplars. A similar recommendation was proposed for the planting of male plants of *Acer negundo* in urban areas to mitigate the risk of spread by samaras, although the production of allergenic pollen must be considered (Ribeiro et al. 2009).

Trees for urban environments are generally selected on the basis of pragmatic criteria, such as suitability for the site, pest resistance or tolerance, availability of stock, and the cultural and aesthetic preferences of local people (Spellerberg and Given 2008). Evidence from Northern and Central Europe shows that in some regions the catalogue of native tree species might be too limited to fulfil ecosystem services and resilience in harsh urban environments (Sjöman et al. 2016). Thus, it might be unrealistic to generally exclude NNTs from consideration for urban greening. Further work is required to quantify the diverse benefits of native species in many contexts. Therefore, we recommend to (a) plant more native trees in urban areas; (b) avoid NNTs if they pose risks to biodiversity or ecosystem services; and (c) plant NNTs only if invasion risk in the surrounding areas is low or can be managed effectively.

At a country level, the recommendation of using native trees in preference of NNTs should be based on sound knowledge of the natural ranges and distribution of native tree species within the country and its regions, to limit translocations across biogeographical regions and safeguard biological integrity of Important Plant Areas (Mehrabian et al. 2020), protected areas, and hot-spots of endemism for trees.

Recommendation 2: Be aware of and comply with international, national, and regional regulations concerning non-native trees

Those engaged in the introduction, breeding, and use of NNTs and in the planted forest sector in general need to be aware of and comply with their obligations under regulations and legislation to prevent the introduction of INNTs and to minimise conflicts with regulatory authorities.

There is a substantial corpus of legally binding and non-binding conventions, regulations, and agreements on invasive non-native species at international, national, and regional levels. The CBD and its Parties recognised that there is an urgent need to address the impact of invasive alien species, and have adopted guidance on prevention, introduction, and mitigation of impacts of alien species that threaten ecosystems, habitats or species, and have taken a number of relevant decisions on invasive alien species, and forest biodiversity (e.g., COP 9 Decision IX/5). The CBD, the UN Climate Change, and UN Desertification Conventions may act synergistically to reduce the negative impacts of INNTs, promoting integrated, coherent, and multi-disciplinary approaches to these related issues and guiding the national forest authorities.

These international conventions have direct and indirect impacts on the everyday work in the planted forest sector and in the use of NNTs. Indeed, international conventions addressing issues of invasive alien species have been ratified by many countries (Shine 2007; Ormsby and Brenton-Rule 2017) and a significant number of NNT species are banned or are subject to restrictions. At national (or subnational) level, many countries have legislation and/or regulations aimed at preventing possession, transport, trade or use of specific (invasive) NNTs (e.g., for Europe see Brundu et al. 2020; Pötzelsberger et al. 2020).

The Regulation (EU) No. 1143/2014 has included in the "list of invasive alien species of [European] Union concern" a number of NNTs – *Acacia saligna*, *Ailanthus altissima*, *Prosopis juliflora*, and *Triadica sebifera* (syn. *Sapium sebiferum*) – totally banning any use of these species in the European Union. This is a very stringent ban, as invasive non-native species of concern in the European Union may not be intentionally: (a) brought into the territory of the Union, including transit under customs supervision; (b) kept, including in contained holding; (c) bred, including in contained holding; (d) transported to, from or within the European Union, except for the transportation of species to facilities in the context of eradication; (e) placed on the market; (f) used or exchanged; (g) permitted to reproduce, grown or cultivated, including in contained holding; or (h) released into the environment.

An example of national-level regulation is that of Mesquite (*Prosopis juliflora*) in the Sudan. This species, native to Mexico, Central America, and northern South America, was introduced to the Sudan in 1917 from South Africa and Egypt and was planted in Khartoum for research purposes. The success of this species in tolerating drought and stabilising sand dunes led to it being introduced to more drought-prone areas. In the 1990s, *P. juliflora* was introduced as part of dune stabilisation programmes in the spate irrigation systems of the Gash and Tokar. However, soon after its introduction *P. juliflora* became invasive. Tens of thousands of hectares were invaded in these areas and a 1995 presidential decree pledged to eradicate the species from Sudan (Laxén 2007). Similarly, *Melaleuca quinquenervia* (a tree native to Australia and Malaysia) was introduced into Florida in 1906 as a potential commercial timber and was later widely sold as an ornamental tree. This species is now on the Federal Noxious Weed List (USDA 2012) because it has invaded all types of terrestrial and wetland habitats, including undisturbed pine flatwoods, sawgrass-dominated communities and cypress swamps, but also roadsides, pastures, and urban sites (Porazinska et al. 2007). For these examples, earlier pro-active regulations on the sale or use of these INNTs could have reduced rates of invasions and impacts.

Recommendation 3: Be aware of the risk of invasion and consider global change trends

Those engaged in the planted forest sector and otherwise in the introduction and use of NNTs need to be aware of the potential for NNTs to become invasive and/or have negative impacts, and to use such information to inform decisions about the selection of trees and the management of plantations. This awareness should be based on the best available knowledge, on experience from elsewhere, and on appropriate assessments of risk, taking into account the existence of time lags in NNTs species spread and impacts (i.e. the "invasion debt", Essl et al. 2011; Rouget et al. 2016) and global change trends.

The fact that some NNTs have not yet spread from the sites where they were planted should not be taken as definitive evidence that spread and negative impacts will not occur in the future. Experience with the same NNTs in planted forests or gardens in other parts of the world, including areas where the species have long residence times (Richardson et al. 2015), should be evaluated to assess the extent of invasion debt since NNTs often have long lag-phases (up to 200–300 years or longer; see Kowarik 1995). There is strong evidence that INNTs can replicate invasive behaviour and impacts in environmentally similar conditions in different parts of the world (Essl et al. 2010).

INNTs included in legally-binding prohibited species or in advisory lists (such as the IUCN list of "100 of the world's worst invasive species", which includes, e.g., *Acacia mearnsii*, *Cinchona pubescens*, and *Leucaena leucocephala*) should not be used in the countries or regions where they are listed, nor released in the environment, nor planted along transport networks, nor used for new planted forests. For example, all new plants (including trees) currently not in New Zealand are banned unless permitted (Hulme 2020). Each new NNT species or provenance planned to be introduced for the first time in a given country or to be planted over large scales which has not yet been evaluated, should be subject to a comprehensive risk analysis to consider opportunities, risks, and management options, with uncertainties explicitly recognised. Moreover, regions or countries should consider not planting NNTs if these taxa are restricted in neighbouring jurisdictions, as NNTs can easily spread across national borders making biosecurity a regional issue (Faulkner et al. 2020). For example, the list of the Israel's "least wanted alien ornamental plant species" includes numerous NNTs which may be relevant for various countries around the Mediterranean, experiencing Mediterranean, semiarid, and arid climates (Dufour-Dror et al. 2013).

More than 100 risk assessment and risk analysis schemes for plant species have been proposed (Křivánek and Pyšek 2006; Leung et al. 2012), and decision-support schemes have been developed specifically for trees or woody plants (Reichard and Hamilton 1997; Pheloung et al. 1999; Kumschick and Richardson 2013; Wilson et al. 2014). Although no global repository currently exists, the European and Mediterranean Plant Protection Organisation (EPPO) platform on pest risk analysis (PRA) contains more than 400 PRAs produced since the early 1990s, including a few for NNTs, and additional documents related to PRA activities. A number of Weed Risk Assessments for NNTs (e.g., *Vachellia nilotica* and *Ligustrum sinense*) are available on-line, e.g., the Noxious Weeds Program Risk Assessments of USDA APHIS (https://www.aphis.usda.gov/aphis/), the PIER (Pacific Island Ecosystems at Risk – Plant threats to Pacific ecosystems; http://www.hear.org/pier/), and the UF/IFAS Assessment of Non-native Plants in Florida's Natural Areas (https://assessment.ifas.ufl.edu/). The result of risk assessments conducted for NNTs in Brazil are available on the web page of the Horus Institute (https://institutohorus.org.br/).

It has been suggested that importers, breeders, and growers who are responsible for introducing potentially invasive non-native species should be responsible for damages to the environment (i.e. the "polluter pays" principle), rather than allowing the burden to be borne by tax payers or neighbouring private landowners (Richardson 1998; Hulme et al. 2008; Buddenhagen et al. 2009; Chimera et al. 2010; McCormick and Howard 2013; Lorentz and Minogue 2015). In addition, contingency plans (EPPO 2009) and effective rapid response measures in the event of escape of NNTs should be in place before the introduction takes place (Rec. 5).

Climate change could affect the dynamics of invasions of NNTs in many interacting ways, for example: (a) by causing modification in the ecosystems that potentially modify opportunities for establishment, naturalisation, and spread of both native trees and NNTs (e.g., Iverson et al. 2008; Bezeng et al. 2017; Fei et al. 2017; Aubin et al. 2018); (b) by favouring individual traits of particular NNTs (e.g., Kawaletz et al. 2013; Castro-Díez et al. 2014); and (c) by modifying introduction pathways, potentially promoting the increased use of certain NNTs (Lindenmayer et al. 2012; Frischbier et al. 2019), thereby challenging the recommendation to preferentially use native trees

(Rec. 1). Climate matching between native and non-native ranges of tree species is often crucial for the outcomes of introducing NNTs (Petitpierre et al. 2012); it is therefore important to incorporate climate change into risk-analysis models for an anticipatory evaluation of scenarios for invasiveness of NNTs. Risk maps that incorporate the effects of climate change should guide land and forest managers and stakeholders with longer-term planning. Land-use change (not only related to the establishment of plantings) is also an important driver of NNTs invasions. Abandonment of land can increase the potential for invasion of NNTs or lead to the establishment of plantations (Lugo 2004, 2015; Sitzia et al. 2012; Mullah et al. 2014; Bravo et al. 2019; Vaz et al. 2019).

Under climate change, outbreaks of pests on native trees might increase, giving a greater momentum to planting NNTs, but these NNTs are also susceptible if pest/pathogens are subsequently accidentally introduced. For example, there has been an alarming increase in impacts of bark beetle outbreaks in conifer forests in recent years in Austria, the Czech Republic, Germany, Slovakia, and in North America (Hlásny et al. 2019). Synchronised by extreme weather, recent bark beetle outbreaks have already reached a supranational scale. Outbreaks are likely to further increase in extent and severity in the future due to climate change (Hlásny et al. 2019). A study in France (Bertheau et al. 2009) supports the assertion that native phytophagous insects adapted rapidly to conifers introduced in Europe. Non-native conifers in France are now colonised by native bark beetles. For risk assessment of native bark beetle attacks on newly introduced conifers, tree taxonomic relatedness appears to be a good predictor of shifting probability and the simplest one to consider in forest management. Planting NNTs within stands of taxonomically unrelated species might therefore reduce the rate of bark beetle shifts into novel hosts (Bertheau et al. 2009). NNTs species are widely used in planted forests for their high productivity and performance compared to native trees. However, these advantages may be compromised by insects and microbial pathogens which were introduced accidentally or have adapted to new host trees (Branco et al. 2015; Wingfield et al. 2015).

Managed relocation or assisted migration has been proposed as an approach to mitigate climate change impacts on biodiversity by intentionally moving species to climatically suitable locations outside their natural range (Richardson et al. 2009). It has also been proposed as a means to maintain forest productivity, health, and ecosystem services under rapid climate change (e.g., Gray et al. 2011; Kreyling et al. 2011; Pedlar et al. 2012; Benito-Garzón and Fernández-Manjarrés 2015; Peterson St-Laurent et al. 2018). This practice has the potential to launch invasions and should be subjected to the same level of risk analysis as for any other type of NNT planting.

Recommendation 4: Design and adopt tailored practices for plantation site selection and silvicultural management

All stakeholders involved in the many activities related to NNTs use, from the nursery industry to the design of plantation, and from silvicultural management to timber harvest, should design and adopt tailored practices to ensure the sustainable use of NNTs and minimise the risk of the escape of NNTs. The nursery industry and public nurseries are key stakeholders (Table 2), as the sustainable supply of germplasm of planting material and its quality is crucial for any tree-based project, from afforestation to restoration and to urban forestry (Broadhurst et al. 2015; Whittet et al. 2016). Nurseries are key stakeholders also for sharing information on native and NNTs (Rec. 8). Commercial horticultural and forest nurseries can act as important hubs of non-native species dissemination to planting sites and urban forest sites. Many weeds and forest pests, both insects and pathogens, have also entered new lands via nursery stock (Liebhold et al. 2012) e.g., *Phytophthora* (Sims et al. 2019), and *Hymenoscyphus fraxineus* (Nielsen et al. 2017). Nurseries are one of the most important sources of unintentional introductions of non-native plants (Hulme et al. 2008). Best-practice methods relating to species and provenances of seed or clones (Karlman 2001), seedling production, weed, pest and disease control should be adopted (FAO 2011). Invasive non-native species and pests should be detected, identified, recorded, notified to competent authorities if mandatory or suggested by the local regulations, and eradicated where possible, before transfers and planting.

Table 2. Stakeholder groups and their expected involvement in the implementation and use of Global Guidelines for the use of Non-Native Trees (GG-NNTs). The classification of stakeholder groups is modified from Raum (2018) and Kleinschmit et al. (2018). Y = Involvement of the stakeholder group in a recommendation (R).

Stakeholder Group	Description	R1	R2	R3	R4	R5	R6	R7	R8
Regulators/Governors/ Public Administrators	National, regional and local governments involved in policy, law making, law enforcement, and incentives. National and regional environmental and forest authorities, public forest agencies, public forest nurseries, protected areas.	Y	Y	Y	Y	Y	Y	Y	Y
Commercial agro-forestry business & industry	Private businesses involved in timber production, harvesting, processing, transport, and trade; water companies; and energy suppliers. Includes confederations of industries.	Y	Y	Y	Y		Y		
Commercial nursery industry	Private businesses involved in tree collection, breeding, trade, etc. Turf and substrata industry.	Y	Y	Y	Y				Y
Forest certification organisations	Independent, non-profit organizations setting standards under which forests and companies are certified.	Y	Y	Y	Y			Y	
Professionals and their organisations or confederations	Individuals providing specialist advice and support, urban forest professionals, landscape architects.	Y	Y	Y	Y	Y	Y		
Academia, science and education	Broad group of individuals and organisations conducting research on biodiversity, forest ecosystems related issues, urban forestry, and providing education. National or international scientific associations such as IUFRO.	Y	Y	Y	Y	Y	Y	Y	Y
Botanic gardens and arboreta	Public or private institutions, including historical gardens where trees are grown for scientific study and display to the public. Confederations such as BGCI.		Y	Y		Y	Y	Y	Y
Private forest owners and their organisations or confederations	Broad groups of individuals and organisations responsible for plantations and woodland management.	Y	Y	Y	Y	Y	Y		
Local or indigenous communities	Local, tribal, and indigenous groups involved either formally or semi-formally in running or managing local woodlands.	Y	Y	Y		Y			
Individuals	Individuals (local) who use (the nearby) woodland or urban forest for numerous purposes, e.g. recreational activities, collection or non-wood forest products, as bee-keepers, hunters, agriculture and grazing.			Y					
General public	Citizen and consumers and their organisations, non-directly using the plantations or the urban forests.			Y					
Media and social media	Media professionals and their organisations, private individuals and organisations, broadcasting and social media platforms.	Y		Y		Y		Y	

Standard biosecurity protocols (Sharma et al. 2014) and phytosanitary measures should be followed and applied, such as the International Standards for Phytosanitary Measures (ISPMs) which are standards adopted by the Commission on Phytosanitary Measures (CPM), which is the governing body of the International Plant Protection Convention (IPPC) (Ormsby and Brenton-Rule 2017). Scouting principles such as those used in integrated pest management are relevant; these require growers to follow a standardised sampling plan to scout large numbers of NNTs efficiently, focussing on key NNT species and vectors that are most susceptible to important pests. Any nursery growing or maintaining ornamental and forest NNTs should have an invasive non-native species and pest control program to prevent the growth of non-native species and NNTs outside sites demarcated for cultivation and around growing areas. Similarly, accidental dispersal of NNT propagules, e.g., through the movement of soil, growing media, equipment, machinery, water, should be avoided. Correct labelling of the nursery material (species and provenances) using scientific names is essential. It is also good practice to use double labels for all seed lots – one label fixed outside the bag, the other inside (Schmidt 2007).

Standards, guidelines, criteria, and indicators for sustainable forest management (SFM) have been developed by intergovernmental processes, international organisations, certification schemes (e.g., Forest Stewardship Council, FSC, and Programme for the Endorsement of Forest Certification schemes, PEFC) (Masiero et al. 2015) and national governments. These recommendations, which apply to all forests including planted forests, have resulted in forestry being recognised as a sustainable form of land-use essential to combatting climate change by storing carbon and preventing deforestation. Activity was increased considerably after the Statement of Principles for the Sustainable Management of Forests was adopted in 1992 at the Earth Summit in Rio in response to global concerns about deforestation and the unsustainable exploitation of natural forests (Stupak et al. 2011). At the European level, the 46 signatories of the Ministerial Conference on the Protection of Forests in Europe agreed on a definition of sustainable forest management in a Ministerial Process dating from 1990 and have developed and refined a set of criteria and indicators. These criteria are regularly updated and adapted to new challenges (https://foresteurope.org/).

Best-management practices include criteria such as that biodiversity issues must be considered in the design of planted forests (Conference of the Parties COP 11 Decision XI/19, 8–19 October 2012, Hyderabad, India). For example, the shape of planted forests comprising NNTs should minimise edges at right angles to prevailing winds during the seed-release season. The establishment of representative natural forest should be encouraged within planted forests and, where possible, natural forests should be restored on appropriate sites (Secretariat of the Convention on Biological Diversity 2009). Plantings of NNTs should be avoided near protected areas or endangered habitats. Because the seeds or other propagules of many INNTs are dispersed in water, consideration must be given to the proximity of planting sites to streams and rivers. Suitable practices for planted forest and urban forestry should also include all available methods to limit the spread of pathogens and pests within planted forests and from infested sites to native forest and other ecosystems (e.g., Engelmark et al. 2001; FAO 2011).

Land managers and owners of planted forests should be informed of forestry activities that favour or limit the spread of NNTs outside plantations (Sitzia et al. 2016). For example, coppicing is known to encourage the spread by *Ailanthus altissima* and *Robinia pseudoacacia.* In South Tyrol, Northern Italy, Radtke et al. (2013) concluded that the currently applied coppice management, involving repeated clearcuttings every 20–30 years, favours the spread of both NNTs. They proposed adaptation of the system to avoid further spread. Vítková et al. (2017) confirmed that, in the absence of forestry interventions, the abundance of *R. pseudoacacia* would decrease during succession in European forests with highly competitive and shade-tolerant trees. However, nearly all lowland forests in Central Europe are managed, which means that these findings are of little value for forestry management in this region unless management plans are totally overhauled. In fact, the limited pool of native woody species, the lack of serious natural enemies, and a dense cover of grasses and sedges can suppress forest succession and favour the development of *R. pseudoacacia* monodominant stands. A stratified approach, combining both tolerance in some areas and strict control at sites of high conservation value, provides the best option for achieving a sustainable coexistence of *R. pseudoacacia* with people and nature (Motta et al. 2009; Vítková et al. 2017, 2020; Sádlo et al. 2017).

The New Zealand guidelines for the use of the Decision Support System (DSS) "Calculating Wilding Spread Risk from New Plantings" (Paul and SCION 2015) are intended to guide individual landowners, consultants, and planners in carrying out initial assessments of wilding spread risk for new afforestation projects. The assessment applies a DSS known as the Wilding Spread Risk Calculator to assess wilding spread risk in a transparent, consistent and repeatable manner using the step-by-step description and examples.

Calviño-Cancela and Rubido-Bará (2013) suggested the establishment of a safety belt around *Eucalyptus* plantations in Spain to reduce the spread of eucalypts from plantations. This measure requires the elimination of all newly recruited individuals in this safety belt (e.g., a 15-m wide belt could reduce the probability of *Eucalyptus* spread by more than 95%) before they start producing seeds, thereby hindering the advance of the front line of invasion. For this purpose, Calviño-Cancela and Rubido-Bará (2013) recommended managing operations at 1–2-year intervals, so that saplings can be removed (uprooted), thus preventing resprouting. Their recommendations apply to situations without fire. Fire stimulates regeneration (Gill 1997; Calviño-Cancela et al. 2018) and could increase dispersal distances, which means that additional measures would probably be needed to control *Eucalyptus* spread after fires. According to Nereu et al. (2019), keeping dense competing vegetation is probably the most cost-effective option to minimise unwanted *E. globulus* recruitment and maximise seedling mortality inside and around plantations. In Portugal, *Eucalyptus* wildlings are more abundant in plantations in moist aspects, coppiced, with older tree stems and corresponding to intermediate site growth indexes (Águas et al. 2017). Silva et al. (2016) undertook an experiment in six regions in Brazil, under different climatic/ecological conditions, with five pure species (*E. camaldulensis*, *E. pellita*, *E. grandis*, *E. urophylla*, and *E. saligna*) and three hybrids. Factors such as competition with other plant species and seedlings predation drastically limited *Eucalyptus* establishment suggesting low ecological adaptation as an invasive species.

Tailored management practices should be followed in the case of planted forests with NNTs for bioenergy production (Short Rotation Forestry SRF, Short Rotation Coppice SRC): choosing new planting sites; mitigating negative impacts on biodiversity (Weih 2008; Framstad et al. 2009; Vanbeveren and Ceulemans 2019); preventing spread into surrounding habitats e.g., using buffer zones (Crosti et al. 2016); protecting hydrology (Christen and Dalgaard 2013); conserving landscape values; and planning for the restoration of the site after the cultivation cycle (Hardcastle et al. 2006; Neary 2013; Caplat et al. 2014). For example, experience with *Eucalyptus* plantations under intensive short-rotation regimes in China (Zhou et al. 2020) suggests that, in the long term, the intensively managed monospecific plantations under short-rotations should be progressively converted into mixed plantations with short-, medium- and long-term rotations. This strategy could be accomplished by interplanting with high-value native tree species such as *Castanopsis hystrix*, *Dalbergia odorifera*, and *Parashorea chinensis*.

Finally, it is very important to design and adopt good practices for harvesting and transport of timber and other forest products or materials, to mitigate the unintentional spread of reproductive material of NNTs by harvest and transport of timber, to reduce the spread of seeds of other weeds, pathogens, and pests inside and outside the plantations. A key requirement of best practice in this regard is to keep forestry machinery out of water bodies and riparian margins. Machinery needs to be cleaned and checked regularly where the transfer of propagules of NNTs species is an identified risk. Although the role of such dispersal has only been studied in a few cases (e.g., Kaplan et al. 2014) it is probably a major factor in invasions of NNTs in many situations. Appropriate water and sediment controls need to be installed to reduce runoff directly into waterways to reduce opportunities for the spread of propagules of NNTs.

Forest personnel and city council staff responsible for working with urban trees should be trained to recognise and report unusual pests and symptoms of diseased or infested trees, to report escape events, and to carry out practices that reduce the risk of pest, NNTs and other non-native species or propagules moving to other locations (Rec. 6). Personnel should wear outer layers of clothing and footwear that are not "seed friendly" (*sensu* USDA 2012) to minimise the risk of spreading INNTs and other invasive non-native species propagules accidentally.

Forest roads (usually built with the primary aims of supporting forest management and harvesting), fire-control ditches, and road and railways networks should be periodically monitored to prevent the escape of NNTs, especially during harvesting or other silvicultural operations that can promote the accidental spread of propagules (Nereu et al. 2019; Chmura 2020). Transport of timber, and other forest products of materials, removing trees or coppice, arboricultural work in urban forestry and mechanisation movement are also responsible for unintentional transport of NNT propagules and other (non-native) species, such as invertebrates, pathogens, and pests.

Recommendation 5: Promote and implement early detection and rapid response programmes

It is very important to regularly monitor plantings for the spread of NNTs and to act rapidly to control spread so that invasions can be managed before they become widespread and costly to control. Early detection and initiation of management to promptly remove INNTs can make the difference between being able to prevent invasions and having to either spend substantial resources controlling widespread invasions or accept or mitigate against whatever negative impacts they have (Nuñez et al. 2017). Proactive measures to reduce the chances of NNT and INNT spread and for dealing with problems at an early stage must be included in standard silvicultural practices, large-scale plantation plans, and urban forestry policies, such as the design of buffer zones around NNT plantations where the potential spread can be monitored more accurately.

The relatively long initial lag phase between introduction and naturalisation/invasion (Kowarik 1995), relative long life span and age of maturity, and slow dynamics observed in many INNTs, compared to other non-native invasive plant species (e.g., aquatic invasive non-native plants), offers opportunities to control the INNTs while escaped populations are still small (Finnoff et al. 2007; Dodet and Collet 2012). Developing "alarm lists" or "alert lists" of possible new invasive NNTs can also enable more rapid reaction (Richardson 2011; Faulkner et al. 2014) as can horizon scanning exercises (e.g., Roy et al. 2014).

Any NNTs detected outside cultivation areas – especially NNTs recognized elsewhere as invasive and/or if occurring in areas of high conservation value – should be georeferenced, reported, and controlled or contained. All records and sightings will help to determine the extent of the INNT problem in a given area and facilitate a rapid response where necessary. They can also help to better understand species distribution, habitat suitability, and thus support better management. Such data should ideally be collected and quality-controlled by a (national / state) coordination centre, so that it can directly inform policy and management. Owing to the huge number of species observations that can be collected by non-professional scientists, citizen science has great potential to contribute to data collection, scientific knowledge on invasive non-native species, and to support early detection for NNTs outside cultivation areas. The recent adoption of information and communications technology in citizen science (e.g., web or mobile application-based interfaces for citizen training and data generation) has led to a massive surge in popularity, mainly due to reduced geographic barriers to citizen participation (Adriaens 2015; Johnson et al. 2020).

A rapid response capacity implies the availability of skilled personnel, contingency plans (where responsibilities are clearly determined), and technical guidelines for controlling invasive NNTs. Guidelines exist for many NNTs (e.g., PM-9 for *Ailanthus altissima*, EPPO 2020) but they need to be incorporated into a unified framework and databases (Rec. 8). It should be stressed that controlling small foci of escaped NNTs, generally saplings, does not require heavy equipment and costly investments. In most cases control can be easily achieved either by cut-stump, drill-fill or hack and squirt techniques that do not require sophisticated tools. In addition, controlling a limited number of NNTs with direct application methods, i.e. without spraying, enables using very small quantities of herbicides. The recent development of new herbicides with high ecotoxicological profiles gives the opportunity to perform INNTs control with a maximum effectiveness and a minimum risk for the environment (Dufour-Dror and Yaacoby 2019).

Establishing a new sentinel garden or joining a network of sentinel sites is an important tool for supporting early detection and early waring strategies. This approach provides the unique opportunity to monitor NNTs in sentinel site networks (Kenis et al. 2018) both for their susceptibility to pathogens and pests, and for their ability to naturalise and to escape from cultivation. Other areas that worth monitoring as they are likely to act as sources of propagules and sites of entry for new invasions are urban areas, areas of human habitation outside large towns where gardens have been established (Alston and Richardson 2006; McLean et al. 2017), experimental plantings, arboreta or botanical gardens containing NNTs (Dawson et al. 2008), networks of non-native monumental trees. They can also be included in sentinel networks (Roques et al. 2015).

Kenis et al. (2018) and Visser et al. (2014) believe that sentinel site networks as described above could help to: (1) identify emerging trends in NNT invasions; (2) provide valuable mapping for particular NNTs; (3) monitor changes in NNT abundance and distribution over time; (4) help ensure legislative compliance of land managers and plantation owners; and (5) track management efforts over time. The International Plant Sentinel Network (IPSN; https://www.plantsentinel.org/), was developed to facilitate collaboration amongst institutes around the world, with a focus on linking botanic gardens and arboreta, National Plant Protection Organisations (NPPOs), and plant health scientists, focusing on pests and pathogen, but it might also help in monitoring NNTs.

Efficient monitoring activities require carefully planning, large and permanent funding and skilled personnel, but important contributions can be done even with limited resources. For example, Visser et al. (2014) showed that Google Earth can be used to establish a global sentinel site network for NNT invasions, because imagery is continuously being updated, is free to access and is low-tech. The ease of accessing Google Earth, potentially linked with projects in platforms such as iNaturalist (https://www.inaturalist.org/), means that effective monitoring of networks of sentinel sites could be achieved as part of citizen science initiatives. Google Street View has been used to detect eucalypt wildlings along roads in Portugal (Deus et al. 2016).

Recommendation 6: Design and adopt tailored practices for invasive non-native tree control, habitat restoration, and for dealing with highly modified ecosystems

If an INNT species has been introduced and started to spread beyond a planting site, early detection and rapid response is crucial to prevent its establishment. The preferred response is to eradicate the INNTs as soon as possible (UNEP/CBD/COP VI/23, principle 13). If eradication is not feasible, containment, and long-term control measures should be implemented. It is often not clear how INNTs can be successfully managed, but there are examples from Australia and South Africa where integrated management approaches are applied, including chemical, physical, biological (Hill et al. 2020), and cultural control (Richardson et al. 2015; van Wilgen et al. 2020). As with other invasive non-native species, a clear definition of the management goals and a spatially coordinated management strategy are key for successful management of INNTs.

It is necessary to develop and adopt species-specific and site-specific guidelines for the restoration of sites previously occupied by INNTs or by planted forests of NNTs, to minimise or reverse disturbances caused by the previous land use or INNTs. In fact, recent international commitments have paved the way for the implementation of large-scale ecological restoration programs in the upcoming decades (https://www.decadeonrestoration.org/), such as the Initiative 20×20 in Latin America and the Caribbean (https://initiative20x20.org/) that seeks to restore 20 million hectares of degraded land by 2020, the AFR100 African Forest Landscape Restoration Initiative (afr100.org) that aims to bring 100 million hectares of degraded land under restoration by 2030 (Chazdon et al. 2017), and the Atlantic Forest Restoration Pact, which aims at restoring 15 million hectares in the Brazilian Atlantic Forest until 2050 (Pinto et al. 2014).

Restoration objectives have been broadly classified into overarching strategies, such as rehabilitation, reconstruction, reclamation, and replacement (see Stanturf et al. 2014). Native tree species can grow in the understory of planted forests of NNTs. However, not all planted forests of NNTs develop species-rich understories; some remain NNT monocultures. Low light intensity below the canopy, distance to seed sources, inhospitability to seed dispersers, altered soil and litter conditions affecting seed germination or seedling growth, intensive root competition with the planted NNTs, other forms of plant-soil interactions, plantation design, or periodic disturbances by organisms or any external factor are likely causes of the lack of native species diversity in NNT planted forests that require careful consideration (Lugo 1997). Thus, human-mediated restoration is likely necessary after the presence of NNTs. One option is the continuous change of the plantation by reducing the abundance of NNTs and simultaneous replanting with native species.

Sádlo et al. (2017) proposed a stratified approach to the management of eight types of *Robinia pseudoacacia* stands growing in Europe, based on decisions that reflect the local context. Specific guidelines for restoration of sites previously occupied by planted forests of *R. pseudoacacia* have been produced in the Piedmont region of Italy and in China (Zhang et al. 2018). Sturgess and Atkinson (1993) suggested management strategies for the restoration of near-natural sand dune habitats following the clearfelling of *Pinus* planted forests in Britain, and Brown et al. (2015) proposed approaches for restoring areas previously planted with non-native conifers on ancient woodland sites. Szitár et al. (2014) assessed the recovery of open and closed grasslands over five years after the removal of planted forests of non-native pine species through burning in an inland sand dune system in Hungary. Arévalo and Fernández-Palacios (2005) proposed the continuous elimination of the non-native *P. radiata* and augmentation with the native *P. canariensis* on Tenerife, Canary Islands (Spain). Hughes and Richards (2003) and Moss and Monstadt (2008) proposed management guidelines for the restoration of floodplain forests in Europe. Detailed guidelines are available for the restoration of South African fynbos vegetation following the clearing of NNTs (Holmes et al. 2000, 2005, 2008; Hirsch et al. 2020; Holmes et al. 2020a, b).

The Atlantic Forest in the Brazil biodiversity hotspot is being threatened by its replacement for *Eucalyptus* plantations (Joly et al. 2014). In many regions, small remnants of Atlantic Forest currently persist in a matrix of *Eucalyptus* plantations (Tavares et al. 2019). Restoration plantations in this biome must be established with nursery-grown seedlings of high genetic diversity (Sujii et al. 2017). Inbreeding depression in trees may lead to reduced tree population viability in forest restoration areas. This issue may play an even more relevant role in restoration plantations in the tropics because most tree species are pollinated by animals, and their maximum flight distances are not considered when distributing seedlings in the field (Sujii et al. 2017).

Active restoration of ecosystems degraded by INNTs to pre-invasion or pre-degradation conditions is impractical in some situations for logistical or financial reasons. In such cases, options for managing such ecosystems sustainably to optimise biodiversity and considerations relating to key ecosystem services should be explored, and guidelines should be formulated for integration into regional management plans (e.g., Schwartz et al. 2012). Management interventions involving inexpensive measures to encourage spontaneous succession following the removal of NNTs or other degrading disturbances are removed or reduced ("passive restoration") have been successful in many regions (see Holmes et al. 2020b for a review). Engagement with all stakeholders is crucial in restoration and control programmes pertaining to NNTs (Rec. 7).

Recommendation 7: Engage with stakeholders on the risks posed by invasive non-native trees, the impacts caused, and the options for management

Stakeholder engagement and public participation are key in the management of risks posed by NNTs and INNTs. The crucial role of stakeholder engagement is increasingly recognized globally, but engagement still implemented mostly in a top-down fashion (Shackleton et al. 2019); much more attention is needed to co-design, co-create and co-implement research and management. Social learning and feedback to stakeholders also need to be promoted, and multidisciplinary collaboration and partnerships are also highly beneficial (Rec. 8).

Forest and forestry issues have become more complex in recent decades. The many uses of forests, of NNTs, and the related types of land uses, now benefit a wider stratum of people than ever before, and is subject to a large range of social and environmental demands. An example of one possible classification of the major stakeholder groups involved in forest and forestry issue, and which are differentially affected by the GG-NNTs, is reported in Table 2. It is a general classification, to be applied only to the GG-NNTs, and cannot substitute national and local analysis of the forest and forestry systems and dedicated stakeholder's maps for local implementations of the GG-NNTs.

It is always important to consider that many NNTs, planted for production or for other purposes, have strong direct positive economic impacts on the local and national economies of many countries, including poverty alleviation, but often lead to sharp conflicts of interest when the NNT species become invasive, and have negative impacts on the ecosystem (Dodet and Collet 2012; van Wilgen and Richardson 2012; Dickie et al. 2014; Sladonja et al. 2015). Such conflicts can be reinforced if risk assessment methods are not transparent or do not give adequate consideration to the context-dependence of impacts (Bartz and Kowarik 2019).

Besides land managers, forest owners, and local or indigenous communities, engagement with the general public is very important for issues related to NNTs, from their use in gardening and landscaping to forests and forestry. The active and informed participation of communities and stakeholders affected by planted forest management decisions is critical to the credibility and acceptance of management processes. Public awareness-raising and communication activities play critical roles in informing and educating the public (Andreu et al. 2009; Marchante et al. 2011; Schreck Reis et al. 2013), thereby allowing them to participate more effectively in decision-making and in the management of NNTs and INNTs (Dechoum et al. 2019). Public support for eradication, management or control efforts directed at INNTs must be sought through carefully planned, long-term ongoing outreach initiatives involving, among other things, meetings with stakeholders, local village leadership, employment of villagers from areas adjacent to invasions, and the effective use of media outlets (Novoa et al. 2018).

An increasing number of tourists are interested not only in experiencing unique natural and cultural environments and landscapes but also learning more about them. Forest-based tours are an ideal opportunity to share information about different types of forest environments, native and NNT species, restoration actions, wildlife and landscapes, how they function, and how they came to be. Visitors are also likely to be interested in the lifestyles, cultures, and social and political histories of local communities living near forest areas and making use of local tree species. Citizen science projects such as online apps for collecting data on distribution and impacts of INNTs (Groom et al. 2017, 2019) should be utilized. Wider engagement and education regarding impacts can be through online sources or field guides (Rotherham and Lambert 2012; Veenvliet et al. 2019).

Since 1992, the UNCED Statement of Forest Principles (Galizzi and Sands 2004) states that the provision of timely, reliable, and accurate information on forests and forest ecosystems is essential for public understanding and informed decision-making and should be ensured (principle 2, letter c). Similarly, the CBD COP 6 Decision VI/23 "Alien species that threaten ecosystems, habitats or species", within its Guiding Principle no. 8 stresses the importance of the process of the exchange of information on invasive alien species.

In formulating legislation on NNTs and INNTs a further application of the participatory approach from regulators, governors, and the public administration in general is envisaged. The aim of participatory forestry is to ensure that all stakeholders are included in all aspects of forest management, decision-making and policy formulation (FAO 2010a). It is often remarked that the public is more likely to comply with regulations that they have actively participated in creating (Sudirman et al. 2004). However, there is diverse criticism regarding the ability to successfully design participatory forest policy processes (Kleinschmit et al. 2018). For example, in Ghana, it has been suggested that involving the public can be disruptive, costly, time consuming, and inefficient, because they are "unable to participate effectively" (Mohammed 2013). On the contrary, many publications identify key factors for successful participation (Kleinschmit et al. 2018), dedicated novel tools, such as the Participatory Technology Assessment (Griessler 2012), Co-Design (Blomkamp 2018), or show how participatory tools in forest policy, legislation making and forest management (e.g., in Tanzania; Magessa et al. 2020) can also help in achieving a number of UN Sustainable Development Goals (https://sdgs.un.org/).

Participatory forestry in the context of NNTs should include professionals from the invasion science sector, as scientific knowledge and evidence are usually conceived outside of policy systems and legislation corpus, and then brokered or disseminated into the policy process, with varying degrees of success (Cairney and Oliver 2017; Pineo et al. 2020).

Recommendation 8: Develop and support global networks, collaborative research and information sharing on native and non-native trees

Global networks, collaborative research, and information sharing are crucial for supporting the implementation of the recommendations of the GG-NNTs and for achieving their goals. Thus, this final recommendation is cross-cutting and relevant to all the other recommendations.

For example, the preferential use of native trees has to be supported by large-scale efforts for the conservation and evaluation of forest genetic resources (Sigaud 2000), from dedicated research in forest tree breeding and improvement, particularly in developing countries. These collaborations and research programmes are essential for the adaptation and the evolutionary processes of trees and forests, for improving their resilience and productivity, and for providing suitable materials and information to the nursery sector on native and NNTs. To date, forest trees are underrepresented among available plant genome sequences (Holliday et al. 2017).

Another important field, and a critical aspect of collaborative research in the management of NNTs and INNTs, is the need for defining and identifying NNT species, since species are the unit tied to regulatory policies and management (Hamelin and Roe 2020). However, a large number of NNTs are used, including thousands of cultigens (hybrids, clones, etc.); for many NNTs, further studies on biosystematics, phylogenetics, taxonomy, nomenclature, and biogeography (e.g., an accurate delineation of native, neonative *sensu* Essl et al. (2019), non-invasive, and invasive geographic ranges) are vital to reproducibility, documentation, and prediction. Lack of concern for nomenclature can undermine science and management of NNTs, and it can lead to serious mistakes. Furthermore, the CBD has long recognised that taxonomy is crucial for the implementation and monitoring of the CBD itself (Global Taxonomy Initiative, Decision IV/1).

Fast and reliable identification of NNTs and INNTs is also a prerequisite of early detection and rapid response (Rec. 5). Global networks and collaborative research can advance application of novel techniques, such as remote microscopy facilitating real-time identification of NNTs (Thompson et al. 2011). This task is achieved by using web-enabled video cameras mounted on microscopes, allowing live streaming of images to a web address. This web link can then be accessed by anybody (e.g., a specialist taxonomist for that NNT species) with access to the Internet. Direct communication between an expert and a specimen holder using remote microscopy equipment facilitates a very high level of interactivity (Thompson et al. 2011).

Global networks (Packer et al. 2017) are critical for the future of invasion science, and to ensure effective planning and management of NNTs to deal with, among other things: identifying global priorities for research and management agendas; coordinating data collection over space and time; assessing risks and emerging trends; understanding the complex influences of biogeography on mechanisms of invasion; predicting the future of invasion dynamics; and using the insights on all of the aforementioned issues to improve the efficiency and effectiveness of evidence-based management techniques.

The scientific community should support the improvement of standard and accepted methods to assess negative impacts of INNTs, establish priorities for intervention, and provide improved tools for comparing species (Bindewald et al. 2019), habitats and regions at the global level. In 2020 the IUCN adopted as a formal standard the Environmental Impact Classification for Alien Taxa (EICAT) methodology (Hawkins et al. 2015; IUCN 2020). Consideration should be given to assessing the impact of INNTs using EICAT. Results of such assessments should be shared using freely accessible platforms such as the IUCN Global Invasive Species Database. An important example of global network is the CONTAIN project, supported by a group of more than 20 researchers from four countries (Argentina, Brazil, Chile, and the UK) with diverse research focuses, such as invasion ecology of plants and animals, ecological restoration, economy, statistics, and social dimensions of invasions, which aims to design, and introduce to stakeholders a user-friendly decision making tool that will help to guide the long-term management of invasive species (Lambin et al. 2020).

Cavender and Donnelly (2019) called for greater involvement of botanical gardens and arboreta with urban forestry to improve sustainability of cities and human lives. These institutions have a significant public reach, maintain strong professional networks, and can make important contributions to addressing key priorities including protecting existing trees; improving tree selection, diversity, and age structure; and improving planning, standards, training, and management. Improving urban forests is one of the solutions to achieving several of the UN SDGs, such as making cities healthier and more liveable (Fig. 1). With the cooperation of practitioners involved in forest and urban forest management, best practice manuals for control or eradication for the most important INNT species can be prepared for different world regions and taxa.

Information on NNTs and INNTs and strategies for dealing with them is critical for the implementation of all the recommendations in the GG-NNTs. Science-based strategies to tackle biological invasions depend on recent, accurate, well-documented, standardised, and openly accessible information on non-native species (Hulme and Weser 2011; Groom et al. 2017). Information is becoming more easily accessible (e.g., IUCN Global Invasive Species Database, www.iucngisd.org, IUCN Global Register of Introduced and Invasive Species, http://www.griis.org/, and CABI Invasive Species Compendium, www.cabi.org/ISC). For INNTs of concern in the European Union, IUCN provided comprehensive information on costs and available methods of appropriate management actions. Such science-based reviews are also available from the EPPO website; an example is the PM/9 Standard on *Ailanthus altissima* (EPPO 2020). The European National Forest Inventory Network (ENFIN) is a facilitator for enhancing harmonisation and comparability of national data and the ancillary information required to monitor European forestry-related policies (Vidal et al. 2016). Similarly, the *Observatoire des Forêts d'Afrique Centrale* (OFAC) is an association of public and private bodies, researchers and NGOs whose goal is to help set up the convergence plan of *Commission des Forêts d'Afrique Centrale* (COMIFAC). It provides COMIFAC and country members a powerful steering and national or remote sensing data sharing platform to promote better governance and the sustainable management of forest ecosystems (Vidal et al. 2016).

However, there is the need to improve the quality and quantity of the available information, and support and use systems for information sharing. For example, the precise geographical distribution of plantations of NNTs is not available for many countries. Harmonised and quality-controlled data at the regional scale (e.g., for the European Union) are needed for robust assessments of responses of forest tree species to climate change (Serra-Diaz et al. 2018; Reyer et al. 2019; Ruiz-Benito et al. 2020).

Information sharing systems would greatly improve the ability of authorities to prevent the introduction and spread of INNTs (Katsanevakis et al. 2013; Tsiamis et al. 2016). Up-to-date and accurate data are also particularly relevant for "horizon scanning" initiatives, which are an essential component of invasive species management, to prioritise potential new invaders that are not yet naturalized in a region (Groom et al. 2015).

Global networks, collaborative research, and information sharing are also crucial to adequately design and promote forest and forestry biosecurity training programmes, in building and developing capacity. In fact, the effective management of NNTs and INNTs, from prevention to early detection and rapid response, from habitat restoration to stakeholder engagement, requires a breadth of expertise from field to laboratory, and specialised knowledge and skills that can only be developed over time. The capacity and awareness of landowners, forestry officials, nursery personnel, and other stakeholders are crucial for effective implementation of the recommendations of the GG-NNTs, as is their hands-on experience to help design training programmes or adjust and improve existing guidelines.

A number of universities offer graduate and postgraduate certification and diplomas on plant biosecurity. Skill development includes, for example, knowledge of the legislative frameworks underlying the regulation of transboundary movement of potentially invasive non-native species, the identification and analysis of pathways and vectors, writing risk assessments for new species (pre-border and post-border), developing incursion response plans, biodiversity management plans, and research proposals, as well as gaining advanced science communication skills. Other important topics include training on pest and pathogen risks to forestry (Marzano et al. 2017), and the use of plant protection products. A single full curriculum dedicated to biosecurity for NNTs is not yet available; there is thus scope for collaborative research aimed at implementing and sharing online training for everyone who might be interested.

Conclusions

A large and growing number of NNTs are invasive in their new ranges and have diverse negative impacts on biodiversity and ecosystem functioning, as well as on Nature's Contribution to People (Díaz et al. 2018). The GG-NNTs call for the preferential use of native trees whenever possible, aims to raise awareness and contribute to reducing the further introduction and spread of new INNTs and further dissemination of known invaders. Where the use of NNTs is unavoidable, the GG-NNTs call for the application of best practices to guide NNT cultivation to minimise the risk of escape from areas set aside for plantings and to ensure that measures are in place to control wildings in the early stage of the invasion process. The application of the GG-NNTs and the achievement of their goals will help to conserve forest biodiversity, ensure sustainable forestry, and contribute to the achievement of a number of Sustainable Development Goals linked with forest biodiversity.

The GG-NNTs outlined in this paper are general; they need to be modified for implementation in different national, regional, and local-scale contexts, in consultation and with full engagement of all relevant stakeholders. Different groups of stakeholders have different fundamental and unreplaceable roles in formulating workable management strategies. For example, in the stakeholder group that includes regulators, governors, and public administration, key expectations are to: make pledges to mobilise resources; build and develop capacity; mainstream the GG-NNTs into national and sub-national policies, regulations, strategies and plans, to prevent NNTs invasions and ecosystem degradation; and to support collaborative scientific research and delivering of technical solutions for the sustainable management of plantations of native trees and NNTs.

The GG-NNTs offer general recommendation on NNTs and provide a basic framework and suggestions on tools for planning and implementing sustainable use of NNTs in nationally appropriate and scientifically sound practices that account for national and sub-national needs. It is important to bear in mind that national circumstances vary considerably in terms of biophysical conditions (e.g., NNT species, forest types, and forest and forestry utilization practices), institutional and legal frameworks, economic challenges and possibilities, management, and use, among other factors. Therefore, no "one-size-fits-all" approach can be applied in the implementation of the GG-NNTs. Instead, various technical and organisational options must be combined to achieve efficient implementation of the guidelines.

Global networks, collaborative research, and information sharing are crucial for supporting the implementation of the recommendations of the GG-NNTs and for achieving their goals. This is the main cross-cutting recommendation. However, other recommendations or parts of them are somewhat cross-cutting and relevant to the whole set of GG-NNTs, such as the need to consider global change trends and to engage with all relevant stakeholders. In fact, tree species, provenance, and site selection, plantation management, evaluation of risks and benefits in the use on NNTs, restoration, and conservation activities are all expected to be strongly influenced by changes in climate and land use.

Finally, in the implementation phase, intersectoral collaboration within the country or within regions should be promoted. Sectors such as agriculture, environmental protection, biodiversity conservation, ecotourism development, and other social fields will be interested in the process of local implementation and in the results of applying the GG-NNTs to the country scale. This involvement may lead not only to greater value at the national level, but also to greater understanding, acceptance of and support for the guidelines. Ideally, the goals of the GG-NNTs should be embedded in national strategies on biodiversity and invasive non-native species. Forest certification schemes are important instruments for mainstreaming the recommendations in the GG-NNTs.

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References

Aarrestad PA, Myking T, Stabbetorp OE, Tollefsrud MM (2014) Foreign Norway spruce (*Picea abies*) provenances in Norway and effects on biodiversity. NINA report 1075, 39 pp.

Abbas AM, Rubio-Casal AE, De Cires A, Grewell BJ, Castillo JM (2019) Differential tolerance of native and invasive tree seedlings from arid African deserts to drought and shade. South African Journal of Botany 123: 228–240. https://doi.org/10.1016/j.sajb.2019.03.018

Adriaens T (2015) Trying to engage the crowd in recording invasive alien species in Europe: experiences from two smartphone applications in northwest Europe. Management of Biological Invasions 6: 215–225. https://doi.org/10.3391/mbi.2015.6.2.12

Águas A, Larcombe MJ, Matias H, Deus E, Potts BM, Rego FC, Silva JS (2017) Understanding the naturalization of *Eucalyptus globulus* in Portugal: a comparison with Australian plantations. European Journal of Forest Research 136: 433–446. https://doi.org/10.1007/s10342-017-1043-6

Aitken SN, Yeaman S, Holliday JA, Wang T, Curtis-McLane S (2008) Adaptation, migration or extirpation: climate change outcomes for tree populations. Evolutionary Applications 1: 95–111. https://doi.org/10.1111/j.1752-4571.2007.00013.x

Alfaro RI, Fady B, Vendramin GG, Dawson IK, Fleming RA, Sáenz-Romero C, Lindig-Cisneros RA, Murdock T, Vinceti B, Navarro CM, Skrøppa T, Baldinelli G, El-Kassaby YA, Loo J (2014) The role of forest genetic resources in responding to biotic and abiotic factors in the context of anthropogenic climate change. Forest Ecology and Management 333: 76–87. https://doi.org/10.1016/j.foreco.2014.04.006

Allen CD, Macalady AK, Chenchouni H, Bachelet D, McDowell N, Vennetier M, Kitzberger T, Rigling A, Breshears DD, Hogg EH (Ted), Gonzalez P, Fensham R, Zhang Z, Castro J, Demidova N, Lim J-H, Allard G, Running SW, Semerci A, Cobb N (2010) A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. Forest Ecology and Management 259: 660–684. https://doi.org/10.1016/j.foreco.2009.09.001

Alston KP, Richardson DM (2006) The roles of habitat features, disturbance, and distance from putative source populations in structuring alien plant invasions at the urban/wildland interface on the Cape Peninsula, South Africa. Biological Conservation 132: 183–198. https://doi.org/10.1016/j.biocon.2006.03.023

Andreu J, Vilà M, Hulme PE (2009) An assessment of stakeholder perceptions and management of noxious alien plants in Spain. Environmental Management 43: 1244. https://doi.org/10.1007/s00267-009-9280-1

Arévalo JR, Fernández-Palacios JM (2005) Gradient analysis of exotic *Pinus radiata* plantations and potential restoration of natural vegetation in Tenerife, Canary Islands (Spain). Acta Oecologica 27: 1–8. https://doi.org/10.1016/j.actao.2004.08.003

Aubin I, Boisvert-Marsh L, Kebli H, McKenney D, Pedlar J, Lawrence K, Hogg EH, 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: e02108. https://doi.org/10.1002/ecs2.2108

Ayanu Y, Jentsch A, Müller-Mahn D, Rettberg S, Romankiewicz C, Koellner T (2015) Ecosystem engineer unleashed: *Prosopis juliflora* threatening ecosystem services? Regional Environmental Change 15: 155–167. https://doi.org/10.1007/s10113-014-0616-x

Bacher S, Blackburn TM, Essl F, Genovesi P, Heikkilä J, Jeschke JM, Jones G, Keller R, Kenis M, Kueffer C, Martinou AF, Nentwig W, Pergl J, Pyšek P, Rabitsch W, Richardson DM, Roy HE, Saul W-C, Scalera R, Vilà M, Wilson JRU, Kumschick S (2018) Socio-economic impact classification of alien taxa (SEICAT). Methods in Ecology and Evolution 9: 159–168. https://doi.org/10.1111/2041-210X.12844

Bartz R, Kowarik I (2019) Assessing the environmental impacts of invasive alien plants: a review of assessment approaches. NeoBiota 43: 69–99. https://doi.org/10.3897/neobiota.43.30122

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

Bauduceau N, Berry P, Cecchi C, Elmqvist T, Fernandez M, Hartig T, Krull W, Mayerhofer E, Sandra N, Noring L (2015) Towards an EU Research and Innovation Policy Agenda for Nature-based Solutions & Re-naturing Cities: Final Report of the Horizon 2020 Expert Group on 'Nature-based Solutions and Re-naturing Cities'. https://doi.org/10.2777/765301

Benito-Garzón M, Fernández-Manjarrés JF (2015) Testing scenarios for assisted migration of forest trees in Europe. New Forests 46: 979–994. https://doi.org/10.1007/s11056-015-9481-9

Benra F, Nahuelhual L, Gaglio M, Gissi E, Aguayo M, Jullian C, Bonn A (2019) Ecosystem services tradeoffs arising from non-native tree plantation expansion in southern Chile. Landscape and Urban Planning 190: 103589. https://doi.org/10.1016/j.landurbplan.2019.103589

Bertheau C, Salle A, Rossi J-P, Bankhead-dronnet S, Pineau X, Roux-morabito G, Lieutier F (2009) Colonisation of native and exotic conifers by indigenous bark beetles (Coleoptera: Scolytinae) in France. Forest Ecology and Management 258: 1619–1628. https://doi.org/10.1016/j.foreco.2009.07.020

Bezeng BS, Morales-Castilla I, van der Bank M, Yessoufou K, Daru BH, Davies TJ (2017) Climate change may reduce the spread of non-native species. Ecosphere 8: e01694. https://doi.org/10.1002/ecs2.1694

Bindewald A, Michiels H-G, Bauhus J (2019) Risk is in the eye of the assessor: comparing risk assessments of four non-native tree species in Germany. Forestry: An International Journal of Forest Research 93: 519–534. https://doi.org/10.1093/forestry/cpz052

Blomkamp E (2018) The Promise of Co-Design for Public Policy. Australian Journal of Public Administration 77: 729–743. https://doi.org/10.1111/1467-8500.12310

Bolte A, Ammer C, Löf M, Madsen P, Nabuurs G-J, Schall P, Spathelf P, Rock J (2009) Adaptive forest management in central Europe: Climate change impacts, strategies and integrative concept. Scandinavian Journal of Forest Research 24: 473–482. https://doi.org/10.1080/02827580903418224

Bond WJ (2016) Ancient grasslands at risk. Science 351: 120–122. https://doi.org/10.1126/science.aad5132

Bond WJ, Stevens N, Midgley GF, Lehmann CE (2019) The trouble with trees: afforestation plans for Africa. Trends in Ecology & Evolution 34: 963–965. https://doi.org/10.1016/j.tree.2019.08.003

Bowditch E, Santopuoli G, Binder F, del Río M, La Porta N, Kluvankova T, Lesinski J, Motta R, Pach M, Panzacchi P, Pretzsch H, Temperli C, Tonon G, Smith M, Velikova V, Weatherall A, Tognetti R (2020) What is Climate-Smart Forestry? A definition from a multinational collaborative process focused on mountain regions of Europe. Ecosystem Services 43: 101113. https://doi.org/10.1016/j.ecoser.2020.101113

Branco M, Brockerhoff EG, Castagneyrol B, Orazio C, Jactel H (2015) Host range expansion of native insects to exotic trees increases with area of introduction and the presence of congeneric native trees. Journal of Applied Ecology 52: 69–77. https://doi.org/10.1111/1365-2664.12362

Braun ACh, Troeger D, Garcia R, Aguayo M, Barra R, Vogt J (2017) Assessing the impact of plantation forestry on plant biodiversity: a comparison of sites in central Chile and Chilean Patagonia. Global Ecology and Conservation 10: 159–172. https://doi.org/10.1016/j.gecco.2017.03.006

Bravo SP, Berrondo MO, Cueto VR (2019) Are small abandoned plantations a threat for protected areas in Andean forests? The potential invasion of non-native cultivated species. Acta Oecologica 95: 128–134. https://doi.org/10.1016/j.actao.2018.11.002

Broadhurst LM, Jones TA, Smith FS, North T, Guja L (2015) Maximizing seed resources for restoration in an uncertain future. BioScience 66: 73–79. https://doi.org/10.1093/biosci/biv155

Brown ND, Curtis T, Adams EC (2015) Effects of clear-felling versus gradual removal of conifer trees on the survival of understorey plants during the restoration of ancient woodlands. Forest Ecology and Management 348: 15–22. https://doi.org/10.1016/j.foreco.2015.03.030

Brundu G, Richardson DM (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

Brundu G, Armeli Minicante S, Barni E, Bolpagni R, Caddeo A, Celesti-Grapow L, Cogoni A, Galasso G, Iiriti G, Lazzaro L, Loi MC, Lozano V, Marignani M, Montagnani C, Siniscalco C (2020) Managing plant invasions using legislation tools: an analysis of the national and regional regulations for non-native plants in Italy. Annali di Botanica 10: 1–12. https://doi.org/10.13133/2239-3129/16508

Brus R, Perić S, Pratasiene K, Oršanić M, Nicolescu V-N, Eisold A-M, Đodan M (2018) Non-native tree species in the viewpoint of climate change: chances and opportunities – Croatia as a case study. Šumarski list 142: 401–402. https://doi.org/10.31298/sl.142.7-8.6

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: 533–544. https://doi.org/10.1080/02827581.2019.1676464

Buddenhagen CE, Chimera C, Clifford P (2009) Assessing biofuel crop invasiveness: a case study. PLoS ONE 4: e5261. https://doi.org/10.1371/journal.pone.0005261

Cairney P, Oliver K (2017) Evidence-based policymaking is not like evidence-based medicine, so how far should you go to bridge the divide between evidence and policy? Health Research Policy and Systems 15: 1–35. https://doi.org/10.1186/s12961-017-0192-x

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

Calviño-Cancela M, Lorenzo P, González L (2018) Fire increases *Eucalyptus globulus* seedling recruitment in forested habitats: Effects of litter, shade and burnt soil on seedling emergence and survival. Forest Ecology and Management 409: 826–834. https://doi.org/10.1016/j.foreco.2017.12.018

Campagnaro T, Brundu G, Sitzia T (2018) Five major invasive alien tree species in European Union forest habitat types of the Alpine and Continental biogeographical regions. Journal for Nature Conservation 43: 227–238. https://doi.org/10.1016/j.jnc.2017.07.007

Caplat P, Hui C, Maxwell BD, Peltzer DA (2014) Cross-scale management strategies for optimal control of trees invading from source plantations. Biological Invasions 16: 677–690. https://doi.org/10.1007/s10530-013-0608-7

Carrillo-Gavilán MA, Vilà M (2010) Little evidence of invasion by alien conifers in Europe. Diversity and Distributions 16: 203–213. https://doi.org/10.1111/j.1472-4642.2010.00648.x

Castro-Díez P, Valle G, González-Muñoz N, Alonso Á (2014) Can the life-history strategy explain the success of the exotic trees *Ailanthus altissima* and *Robinia pseudoacacia* in Iberian floodplain forests? PLoS ONE 9: e100254. https://doi.org/10.1371/journal.pone.0100254

Castro-Díez P, Vaz AS, Silva JS, van Loo M, Alonso Á, Aponte C, Bayón Á, Bellingham PJ, Chiuffo MC, DiManno N, Julian K, Kandert S, La Porta N, Marchante H, Maule HG, Mayfield MM, Metcalfe D, Monteverdi MC, Núñez MA, Ostertag R, Parker IM, Peltzer DA, Potgieter LJ, Raymundo M, Rayome D, Reisman-Berman O, Richardson DM, Roos RE, Saldaña A, Shackleton RT, Torres A, Trudgen M, Urban J, Vicente JR, Vilà M, Ylioja T, Zenni RD, Godoy O (2019) Global effects of non-native tree species on multiple ecosystem services. Biological Reviews 94: 1477–1501. https://doi.org/10.1111/brv.12511

Cavender N, Donnelly G (2019) Intersecting urban forestry and botanical gardens to address big challenges for healthier trees, people, and cities. Plants, People, Planet 1: 315–322. https://doi.org/10.1002/ppp3.38

Cazetta AL, Zenni RD (2020) Pine invasion decreases density and changes native tree communities in woodland Cerrado. Plant Ecology & Diversity 13: 85–91. https://doi.org/10.1080/17550874.2019.1675097

Cernansky R (2018) How to rebuild a forest. As projects to restore woodlands accelerate, researchers are looking for ways to avoid repeating past failures. Nature 560: 542–544. https://doi.org/10.1038/d41586-018-06031-x

Chazdon RL, Brancalion PHS, Lamb D, Laestadius L, Calmon M, Kumar C (2017) A policy-driven knowledge agenda for global forest and landscape restoration. Conservation Letters 10: 125–132. https://doi.org/10.1111/conl.12220

Chimera CG, Buddenhagen CE, Clifford PM (2010) Biofuels: the risks and dangers of introducing invasive species. Biofuels 1: 785–796. https://doi.org/10.4155/bfs.10.47

Chmura D (2020) The spread and role of the invasive alien tree *Quercus rubra* (L.) in novel forest ecosystems in Central Europe. Forests 11: 1–586. https://doi.org/10.3390/f11050586

Choge S, Pasiecznik N, Harvey M, Wright J, Awan S, Harris P (2007) *Prosopis* pods as human food, with special reference to Kenya. Water SA 33: 419–424. https://doi.org/10.4314/wsa.v33i3.49162

Christen B, Dalgaard T (2013) Buffers for biomass production in temperate European agriculture: a review and synthesis on function, ecosystem services and implementation. Biomass and Bioenergy 55: 53–67. https://doi.org/10.1016/j.biombioe.2012.09.053

Crosti R, Agrillo E, Ciccarese L, Guarino R, Paris P, Testi A (2016) Assessing escapes from short rotation plantations of the invasive tree species *Robinia pseudoacacia* L. in Mediterranean ecosystems: a study in central Italy. iForest – Biogeosciences and Forestry 9: 822–828. https://doi.org/10.3832/ifor1526-009

Davis KT, Maxwell BD, Caplat P, Pauchard A, Nuñez MA (2019) Simulation model suggests that fire promotes lodgepole pine (*Pinus contorta*) invasion in Patagonia. Biological Invasions 21: 2287–2300. https://doi.org/10.1007/s10530-019-01975-1

Dawson W, Mndolwa AS, Burslem DFRP, Hulme PE (2008) Assessing the risks of plant invasions arising from collections in tropical botanical gardens. Biodiversity and Conservation 17: 1979–1995. https://doi.org/10.1007/s10531-008-9345-0

Dechoum M de S, Giehl ELH, Sühs RB, Silveira TCL, Ziller SR (2019) Citizen engagement in the management of non-native invasive pines: does it make a difference? Biological Invasions 21: 175–188. https://doi.org/10.1007/s10530-018-1814-0

Deus E, Silva JS, Catry FX, Rocha M, Moreira F (2016) Google Street View as an alternative method to car surveys in large-scale vegetation assessments. Environmental Monitoring and Assessment 188: a560. https://doi.org/10.1007/s10661-016-5555-1

Díaz S, Pascual U, Stenseke M, Martín-López B, Watson RT, Molnár Z, Hill R, Chan KMA, Baste IA, Brauman KA, Polasky S, Church A, Lonsdale M, Larigauderie A, Leadley PW, van Oudenhoven APE, van der Plaat F, Schröter M, Lavorel S, Aumeeruddy-Thomas Y, Bukvareva E, Davies K, Demissew S, Erpul G, Failler P, Guerra CA, Hewitt CL, Keune H, Lindley S, Shirayama Y (2018) Assessing nature's contributions to people. Science 359: 270–272. https://doi.org/10.1126/science.aap8826

Dickie IA, Bennett BM, Burrows LE, Nuñez MA, Peltzer DA, Porté A, Richardson DM, Rejmánek M, Rundel PW, van Wilgen BW (2014) Conflicting values: ecosystem services and invasive tree management. Biological Invasions 16: 705–719. https://doi.org/10.1007/s10530-013-0609-6

Dodet M, Collet C (2012) When should exotic forest plantation tree species be considered as an invasive threat and how should we treat them? Biological Invasions 14: 1765–1778. https://doi.org/10.1007/s10530-012-0202-4

Douglas DJT, Nalwanga D, Katebaka R, Atkinson PW, Pomeroy DE, Nkuutu D, Vickery JA (2014) The importance of native trees for forest bird conservation in tropical farmland. Animal Conservation 17: 256–264. https://doi.org/10.1111/acv.12087

Dufour-Dror J-M, Fragman-Sapir O, Avishai M, Valczak M, Yaacoby T, Kagan S, Vered-Leshner H, Galon I, Heller A, Gotlieb A (2013) Israel's Least Wanted Alien Ornamental Plant Species – Ornamental Plants Potentially Invasive in Israel's Natural Ecosystems (1st edn). 21 pp.

Dufour-Dror J-M, Yaacoby T (2019) Control of *Acacia saligna* with aminopyralid direct application: new perspectives in the control management of one of the most widespread invasive wattle species. In: Pyšek P, Pergl J, Moodley D (Eds) EMAPi 2019 – Integrating research, management and policy – Book of Abstracts. Institute of Botany, Czech Academy of Sciences, Prague, 81 pp. https://emapi2019.org/wp-content/uploads/2019/09/book_of_abstracts2.pdf

Endreny TA (2018) Strategically growing the urban forest will improve our world. Nature Communications 9: 1160. https://doi.org/10.1038/s41467-018-03622-0

Engelmark O, Sjöberg K, Andersson B, Rosvall O, Ågren GI, Baker WL, Barklund P, Björkman C, Despain DG, Elfving B, Ennos RA, Karlman M, Knecht MF, Knight DH, Ledgard NJ, Lindelöw Å, Nilsson C, Peterken GF, Sörlin S, Sykes MT (2001) Ecological effects and management aspects of an exotic tree species: the case of lodgepole pine in Sweden. Forest Ecology and Management 141: 3–13. https://doi.org/10.1016/S0378-1127(00)00498-9

EPPO (2009) PM 9/10(1): Generic elements for contingency plans. EPPO Bulletin 39: 471–474. https://doi.org/10.1111/j.1365-2338.2009.02332.x

EPPO (2020) PM 9/29 (1) *Ailanthus altissima*. EPPO Bulletin 50: 148–155. https://doi.org/10.1111/epp.12621

Escobedo FJ, Giannico V, Jim CY, Sanesi G, Lafortezza R (2019) Urban forests, ecosystem services, green infrastructure and nature-based solutions: Nexus or evolving metaphors? Urban Forestry & Urban Greening 37: 3–12. https://doi.org/10.1016/j.ufug.2018.02.011

Essl F, Moser D, Dullinger S, Mang T, Hulme PE (2010) Selection for commercial forestry determines global patterns of alien conifer invasions. Diversity and Distributions 16: 911–921. https://doi.org/10.1111/j.1472-4642.2010.00705.x

Essl F, Dullinger S, Rabitsch W, Hulme PE, Hülber K, Jarošík V, Kleinbauer I, Krausmann F, Kühn I, Nentwig W, Vilà M, Genovesi P, Gherardi F, Desprez-Loustau M-L, Roques A, Pyšek P (2011) Socioeconomic legacy yields an invasion debt. Proceedings of the National Academy of Sciences of the USA 108: 203–207. https://doi.org/10.1073/pnas.1011728108

Essl F, Dullinger S, Genovesi P, Hulme PE, Jeschke JM, Katsanevakis S, Kühn I, Lenzner B, Pauchard A, Pyšek P, Rabitsch W, Richardson DM, Seebens H, van Kleunen M, van der Putten WH, Vilà M, Bacher S (2019) A conceptual framework for range-expanding species that track human-induced environmental change. BioScience 69: 908–919. https://doi.org/10.1093/biosci/biz101

FAO (2010a) Developing Effective Forest Policy. A guide. FAO, Rome, 69 pp. http://www.fao.org/3/i1679e/i1679e00.htm [May 10, 2020]

FAO (2010b) Planted Forests in Sustainable Forest Management. A Statement of Principles. FAO, Rome, 16 pp. http://www.fao.org/docrep/012/al248e/al248e00.pdf

FAO (2011) 164 Guide to Implementation of Phytosanitary Standards in Forestry. FAO, Rome, 165 pp. http://www.fao.org/3/i2080e/i2080e00.htm

FAO (2020) Global Forest Resources Assessment 2020. FAO, Rome, 16 pp. https://doi.org/10.4060/ca8753en

Faulkner KT, Robertson MP, Wilson JRU (2020) Stronger regional biosecurity is essential to prevent hundreds of harmful biological invasions. Global Change Biology 26: 2449–2462. https://doi.org/10.1111/gcb.15006

Faulkner KT, Robertson MP, Rouget M, Wilson JRU (2014) A simple, rapid methodology for developing invasive species watch lists. Biological Conservation 179: 25–32. https://doi.org/10.1016/j.biocon.2014.08.014

Fei S, Desprez JM, Potter KM, Jo I, Knott JA, Oswalt CM (2017) Divergence of species responses to climate change. Science Advances 3: e1603055. https://doi.org/10.1126/sciadv.1603055

Finnoff D, Shogren JF, Leung B, Lodge D (2007) Take a risk: preferring prevention over control of biological invaders. Ecological Economics 62: 216–222. https://doi.org/10.1016/j.ecolecon.2006.03.025

Framstad E, Berglund H, Gundersen V, Heikkilä R, Lankinen N, Peltola T, Risbøl O, Weih M (2009) Increased biomass harvesting for bioenergy: effects on biodiversity, landscape amenities and cultural heritage values. Nordic Council of Ministers. https://doi.org/10.6027/tn2009-591

Frischbier N, Nikolova PS, Brang P, Klumpp R, Aas G, Binder F (2019) Climate change adaptation with non-native tree species in Central European forests: early tree survival in a multi-site field trial. European Journal of Forest Research 138: 1015–1032. https://doi.org/10.1007/s10342-019-01222-1

Gaertner M, Biggs R, Te Beest M, Hui C, Molofsky J, Richardson DM (2014) Invasive plants as drivers of regime shifts: identifying high-priority invaders that alter feedback relationships. Diversity and Distributions 20: 733–744. https://doi.org/10.1111/ddi.12182

Galizzi P, Sands P [Eds] (2004) Non-Legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forests, 13 June 1992. Documents in International Environmental Law. Cambridge University Press, Cambridge, 751–758. https://doi.org/10.1017/CBO9781139171380.039

Ge J, Pitman AJ, Guo W, Zan B, Fu C (2020) Impact of revegetation of the Loess Plateau of China on the regional growing season water balance. Hydrology and Earth System Sciences 24: 515–533. https://doi.org/10.5194/hess-24-515-2020

Gill AM (1997) Eucalypts and fires: interdependent or independent. In: Williams JE, Woinarski J (Eds) Eucalypt Ecology: Individuals to Ecosystems. Cambridge University Press, 151–167.

Goffner D, Sinare H, Gordon LJ (2019) The Great Green Wall for the Sahara and the Sahel Initiative as an opportunity to enhance resilience in Sahelian landscapes and livelihoods. Regional Environmental Change 19: 1417–1428. https://doi.org/10.1007/s10113-019-01481-z

Gordon DR, Flory SL, Cooper AL, Morris SK (2012) Assessing the invasion risk of *Eucalyptus* in the United States using the Australian Weed Risk Assessment. In: Kirst M (Ed.) International Journal of Forestry Research 2012: 203768. https://doi.org/10.1155/2012/203768

Gray LK, Gylander T, Mbogga MS, Chen P, Hamann A (2011) Assisted migration to address climate change: recommendations for aspen reforestation in western Canada. Ecological Applications 21: 1591–1603. https://doi.org/10.1890/10-1054.1

Griessler E (2012) One size fits all? On the institutionalization of participatory technology assessment and its interconnection with national ways of policy-making: the cases of Switzerland and Austria. Poiesis & Praxis 9: 61–80. https://doi.org/10.1007/s10202-012-0120-7

Groom Q, Desmet P, Vanderhoeven S, Adriaens T (2015) The importance of open data for invasive alien species research, policy and management. Management of Biological Invasions 6: 119–125. https://doi.org/10.3391/mbi.2015.6.2.02

Groom Q, Strubbe D, Adriaens T, Davis AJS, Desmet P, Oldoni D, Reyserhove L, Roy HE, Vanderhoeven S (2019) Empowering citizens to inform decision-making as a way forward to support invasive alien species policy. Citizen Science: Theory and Practice 4: 1–33. https://doi.org/10.5334/cstp.238

Groom QJ, Adriaens T, Desmet P, Simpson A, De Wever A, Bazos I, Cardoso AC, Charles L, Christopoulou A, Gazda A, Helmisaari H, Hobern D, Josefsson M, Lucy F, Marisavljevic

D, Oszako T, Pergl J, Petrovic-Obradovic O, Prévot C, Ravn HP, Richards G, Roques A, Roy HE, Rozenberg M-AA, Scalera R, Tricarico E, Trichkova T, Vercayie D, Zenetos A, Vanderhoeven S (2017) Seven recommendations to make your invasive alien species data more useful. Frontiers in Applied Mathematics and Statistics 3: 1–13. https://doi.org/10.3389/fams.2017.00013

Hamelin RC, Roe AD (2020) Genomic biosurveillance of forest invasive alien enemies: a story written in code. Evolutionary Applications 13: 95–115. https://doi.org/10.1111/eva.12853

Hanspach J, Kühn I, Pyšek P, Boos E, Klotz S (2008) Correlates of naturalization and occupancy of introduced ornamentals in Germany. Perspectives in Plant Ecology, Evolution and Systematics 10: 241–250. https://doi.org/10.1016/j.ppees.2008.05.001

Hardcastle P, Calder I, Dingwall C, Garret W, McChesney I, Matthew J, Savill P (2006) A review of the potential impacts of short rotation forestry. LTS International Ltd., Penicuik, UK.

Hawkins CL, Bacher S, Essl F, Hulme PE, Jeschke JM, Kühn I, Kumschick S, Nentwig W, Pergl J, Pyšek P, Rabitsch W, Richardson DM, Vilà M, Wilson JRU, Genovesi P, Blackburn TM (2015) Framework and guidelines for implementing the proposed IUCN Environmental Impact Classification for Alien Taxa (EICAT). Diversity and Distributions 21: 1360–1363. https://doi.org/10.1111/ddi.12379

Heywood VH, Brunel S (2011) Code of Conduct on Horticulture and Invasive Alien Plants. Council of Europe Publishing, Strasbourg, 95 pp.

Heywood VH, Sharrock S (2013) European Code of Conduct for Botanic Gardens on Invasive Alien Species. Council of Europe Publishing, Botanic Gardens Conservation International, Richmond, Strasbourg, 51 pp.

Hill MP, Moran VC, Hoffmann JH, Neser S, Zimmermann HG, Simelane DO, Klein H, Zachariades C, Wood AR, Byrne MJ, Paterson ID, Martin GD, Coetzee JA (2020) More than a century of biological control against invasive alien plants in South Africa: a synoptic view of what has been accomplished. In: van Wilgen BW, Measey J, Richardson DM, Wilson JR, Zengeya TA (Eds) Biological Invasions in South Africa. Springer International Publishing, Cham, 553–572. https://doi.org/10.1007/978-3-030-32394-3_19

Hinchee M, Zhang C, Chang S, Cunningham Mi, Hammond W, Nehra N (2011) Biotech Eucalyptus can sustainably address society's need for wood: the example of freeze tolerant *Eucalyptus* in the southeastern U.S. BMC Proceedings 5: I24. https://doi.org/10.1186/1753-6561-5-S7-I24

Hirsch H, Allsopp MH, Canavan S, Cheek M, Geerts S, Geldenhuys CJ, Harding G, Hurley BP, Jones W, Keet J-H, Klein H, Ruwanza S, van Wilgen BW, Wingfield MJ, Richardson DM (2020) *Eucalyptus camaldulensis* in South Africa – past, present, future. Transactions of the Royal Society of South Africa 75: 1–22. https://doi.org/10.1080/0035919X.2019.1669732

Hlásny T, Krokene P, Liebhold A, Montagné-Huck C, Müller J, Qin H, Raffa K, Schelhaas M-J, Seidl R, Svoboda M, Viiri H, European Forest Institute (2019) Living with bark beetles: impacts, outlook and management options. European Forest Institute. From Science to Policy. https://doi.org/10.36333/fs08

Holliday JA, Aitken SN, Cooke JEK, Fady B, González-Martínez SC, Heuertz M, Jaramillo-Correa J-P, Lexer C, Staton M, Whetten RW, Plomion C (2017) Advances in ecological genomics in forest trees and applications to genetic resources conservation and breeding. Molecular Ecology 26: 706–717. https://doi.org/10.1111/mec.13963

Holmes PM, Richardson DM, van Wilgen BW, Gelderblom C (2000) Recovery of South African fynbos vegetation following alien woody plant clearing and fire: implications for restoration. Austral Ecology 25: 631–639. https://doi.org/10.1111/j.1442-9993.2000.tb00069.x

Holmes PM, Esler KJ, Richardson DM, Witkowski ETF (2008) Guidelines for improved management of riparian zones invaded by alien plants in South Africa. South African Journal of Botany 74: 538–552. https://doi.org/10.1016/j.sajb.2008.01.182

Holmes PM, Esler KJ, van Wilgen BW, Richardson DM (2020a) Ecological restoration of ecosystems degraded by invasive alien plants in South African Fynbos: Is spontaneous succession a viable strategy? Transactions of the Royal Society of South Africa: 1–29. https://doi.org/10.1080/0035919X.2020.1781291

Holmes PM, Richardson DM, Esler KJ, Witkowski ETF, Fourie S (2005) A decision-making framework for restoring riparian zones degraded by invasive alien plants in South Africa. South African Journal of Science 101: 553–564.

Holmes PM, Esler KJ, Gaertner M, Geerts S, Hall SA, Nsikani MM, Richardson DM, Ruwanza S (2020b) Biological Invasions and Ecological Restoration in South Africa. In: van Wilgen BW, Measey J, Richardson DM, Wilson JR, Zengeya TA (Eds) Biological Invasions in South Africa. Springer International Publishing, Cham, 665–700. https://doi.org/10.1007/978-3-030-32394-3_23

Hua F, Wang X, Zheng X, Fisher B, Wang L, Zhu J, Tang Y, Yu DW, Wilcove DS (2016) Opportunities for biodiversity gains under the world's largest reforestation programme. Nature Communications 7: 12717. https://doi.org/10.1038/ncomms12717

Hughes F, Richards K (2003) The Flooded Forest-Guidance for policy makers and river managers in Europe on the restoration of floodplain forests-The FLOBAR2 Project. Department of Geography, University of Cambridge, Cambridge.

Hulme PE (2011) Addressing the threat to biodiversity from botanic gardens. Trends in Ecology & Evolution 26: 168–174. https://doi.org/10.1016/j.tree.2011.01.005

Hulme PE (2015) Resolving whether botanic gardens are on the road to conservation or a pathway for plant invasions. Conservation Biology 29: 816–824. https://doi.org/10.1111/cobi.12426

Hulme PE (2020) Plant invasions in New Zealand: global lessons in prevention, eradication and control. Biological Invasions 22: 1539–1562. https://doi.org/10.1007/s10530-020-02224-6

Hulme PE, Weser C (2011) Mixed messages from multiple information sources on invasive species: a case of too much of a good thing? Diversity and Distributions 17: 1152–1160. https://doi.org/10.1111/j.1472-4642.2011.00800.x

Hulme PE, Bacher S, Kenis M, Klotz S, Kühn I, Minchin D, Nentwig W, Olenin S, Panov V, Pergl J, Pyšek P, Roques A, Sol D, Solarz W, Vilà M (2008) Grasping at the routes of biological invasions: a framework for integrating pathways into policy. Journal of Applied Ecology 45: 403–414. https://doi.org/10.1111/j.1365-2664.2007.01442.x

IUCN (2020) IUCN EICAT Categories and Criteria : the Environmental Impact Classification for Alien Taxa (EICAT) : first edition. IUCN, Gland, 22 pp. https://doi.org/10.2305/IUCN.CH.2020.05.en

Iverson LR, Prasad AM, Matthews SN, Peters M (2008) Estimating potential habitat for 134 eastern US tree species under six climate scenarios. Forest Ecology and Management 254: 390–406. https://doi.org/10.1016/j.foreco.2007.07.023

Jackson RB, Banner JL, Jobbágy EG, Pockman WT, Wall DH (2002) Ecosystem carbon loss with woody plant invasion of grasslands. Nature 418: 623–626. https://doi.org/10.1038/nature00910

Jackson RB, Jobbágy EG, Avissar R, Roy SB, Barrett DJ, Cook CW, Farley KA, le Maitre DC, McCarl BA, Murray BC (2005) Trading water for carbon with biological carbon sequestration. Science 310: 1944. https://doi.org/10.1126/science.1119282

Jäger H, Tye A, Kowarik I (2007) Tree invasion in naturally treeless environments: Impacts of quinine (*Cinchona pubescens*) trees on native vegetation in Galápagos. Biological Conservation 140: 297–307. https://doi.org/10.1016/j.biocon.2007.08.014

Johnson BA, Mader AD, Dasgupta R, Kumar P (2020) Citizen science and invasive alien species: An analysis of citizen science initiatives using information and communications technology (ICT) to collect invasive alien species observations. Global Ecology and Conservation 21: e00812. https://doi.org/10.1016/j.gecco.2019.e00812

Joly CA, Metzger JP, Tabarelli M (2014) Experiences from the Brazilian Atlantic Forest: ecological findings and conservation initiatives. New Phytologist 204: 459–473. https://doi.org/10.1111/nph.12989

Jones CG, Lawton JH, Shachak M (1994) Organisms as ecosystem engineers. Oikos 69: 373–386. https://doi.org/10.2307/3545850

Kaplan H, van Niekerk A, Le Roux JJ, Richardson DM, Wilson JRU (2014) Incorporating risk mapping at multiple spatial scales into eradication management plans. Biological Invasions 16: 691–703. https://doi.org/10.1007/s10530-013-0611-z

Karlman M (2001) Risks associated with the introduction of *Pinus contorta* in northern Sweden with respect to pathogens. Forest Ecology and Management 141: 97–105. https://doi.org/10.1016/S0378-1127(00)00492-8

Katsanevakis S, Genovesi P, Gaiji S, Hvid HN, Roy H, Nunes AL, Aguado FS, Bogucarskis K, Debusscher B, Deriu I, Harrower C, Josefsson M, Lucy F, Marchini A, Richards G, Trichkova T, Vanderhoeven S, Zenetos A, Cardoso AC (2013) Implementing the European policies for alien species – networking, science, and partnership in a complex environment. Management of Biological Invasions 4: 3–6. https://doi.org/10.3391/mbi.2013.4.1.02

Kaur R, Gonzáles WL, Llambi LD, Soriano PJ, Callaway RM, Rout ME, Gallaher TJ, Inderjit (2012) Community impacts of *Prosopis juliflora* invasion: biogeographic and congeneric comparisons. PLoS ONE 7: e44966. https://doi.org/10.1371/journal.pone.0044966

Kawaletz H, Mölder I, Zerbe S, Annighöfer P, Terwei A, Ammer C (2013) Exotic tree seedlings are much more competitive than natives but show underyielding when growing together. Journal of Plant Ecology 6: 305–315. https://doi.org/10.1093/jpe/rts044

Kenis M, Li H, Fan J, Courtial B, Auger-Rozenberg M-A, Yart A, Eschen R, Roques A (2018) Sentinel nurseries to assess the phytosanitary risks from insect pests on importations of live plants. Scientific Reports 8: 11217. https://doi.org/10.1038/s41598-018-29551-y

Kleinschmit D, Pülzl H, Secco L, Sergent A, Wallin I (2018) Orchestration in political processes: Involvement of experts, citizens, and participatory professionals in forest policy making. Forest Policy and Economics 89: 4–15. https://doi.org/10.1016/j.forpol.2017.12.011

van Kleunen M, Essl F, Pergl J, Brundu G, Carboni M, Dullinger S, Early R, González-Moreno P, Groom QJ, Hulme PE, Kueffer C, Kühn I, Máguas C, Maurel N, Novoa A, Parepa M, Pyšek P, Seebens H, Tanner R, Touza J, Verbrugge L, Weber E, Dawson W, Kreft H, Weigelt P, Winter M, Klonner G, Talluto MV, Dehnen-Schmutz K (2018) The changing role of ornamental horticulture in alien plant invasions. Biological Reviews 93: 1421–1437. https://doi.org/10.1111/brv.12402

Klug I, Mafra ÁL, Friederichs A, Rech C, Fert Neto J (2020) Atributos químicos do solo em plantios florestais em substituição à vegetação nativa em campos de altitude. Ciência Florestal 30: 279–290. https://doi.org/10.5902/1980509818905

Kowarik I (1995) Time lags in biological invasions with regard to the success and failure of alien species. In: Pysek P, Prach K, Rejmanek M, Wade M (Eds) Plant Invasions – General Aspects and Specific Problems. SPB Academic Publishing, Amsterdam. The Netherlands, 15–38.

Kowarik I, Hiller A, Planchuelo G, Seitz B, von der Lippe M, Buchholz S (2019) Emerging urban forests: opportunities for promoting the wild side of the urban green infrastructure. Sustainability 11: 6318. https://doi.org/10.3390/su11226318

Kreyling J, Bittner T, Jaeschke A, Jentsch A, Jonas Steinbauer M, Thiel D, Beierkuhnlein C (2011) Assisted colonization: a question of focal units and recipient localities. Restoration Ecology 19: 433–440. https://doi.org/10.1111/j.1526-100X.2011.00777.x

Křivánek M, Pyšek P (2006) Predicting invasions by woody species in a temperate zone: a test of three risk assessment schemes in the Czech Republic (Central Europe). Diversity and Distributions 12: 319–327. https://doi.org/10.1111/j.1366-9516.2006.00249.x

Krumm F, Vítková L [Eds] (2016) Introduced Tree Species in European forests: Opportunities and Challenges. European Forest Institute, 423 pp.

Kumschick S, Richardson DM (2013) Species-based risk assessments for biological invasions: advances and challenges. Diversity and Distributions 19: 1095–1105. https://doi.org/10.1111/ddi.12110

Lambin X, Burslem D, Caplat P, Cornulier T, Damasceno G, Fasola L, Fidelis A, García-Díaz P, Langdon B, Linardaki E, Montti L, Moyano J, Nuñez MA, Palmer SCF, Pauchard A, Phimister E, Pizarro JC, Powell P, Raffo E, Rodriguez-Jorquera IA, Roesler I, Tomasevic JA, Travis JMJ, Verdugo C (2020) Optimising the long-term management of invasive alien species using adaptive management. NeoBiota 59: 119–138. https://doi.org/10.3897/neobiota.59.52022

Laxén J (2007) Is prosopis a curse or a blessing? an ecological-economic analysis of an invasive alien tree species in Sudan. University of Helsinki, Viikki Tropical Resources Institute (VITRI). https://researchportal.helsinki.fi/en/publications/is-prosopis-a-curse-or-a-blessing-an-ecological-economic-analysis

Le Maitre DC, van Wilgen BW, Gelderblom CM, Bailey C, Chapman RA, Nel JA (2002) Invasive alien trees and water resources in South Africa: case studies of the costs and benefits of management. Forest Ecology and Management 160: 143–159. https://doi.org/10.1016/S0378-1127(01)00474-1

Leung B, Roura-Pascual N, Bacher S, Heikkilä J, Brotons L, Burgman MA, Dehnen-Schmutz K, Essl F, Hulme PE, Richardson DM, Sol D, Vilà M (2012) TEASIng apart alien species risk assessments: a framework for best practices. Ecology Letters 15: 1475–1493. https://doi.org/10.1111/ele.12003

Li H-P, Wickham JD, Bushley K, Wang Z-G, Zhang B, Sun J-H (2020) New approaches in urban forestry to minimize invasive species impacts: the case of Xiongan New Area in China. Insects 11: 300. https://doi.org/10.3390/insects11050300

Liebhold AM, Brockerhoff EG, Garrett LJ, Parke JL, Britton KO (2012) Live plant imports: the major pathway for forest insect and pathogen invasions of the US. Frontiers in Ecology and the Environment 10: 135–143. https://doi.org/10.1890/110198

Lindenmayer DB, Hulvey KB, Hobbs RJ, Colyvan M, Felton A, Possingham H, Steffen W, Wilson K, Youngentob K, Gibbons P (2012) Avoiding bio-perversity from carbon sequestration solutions. Conservation Letters 5: 28–36. https://doi.org/10.1111/j.1755-263X.2011.00213.x

Linders TEW, Schaffner U, Eschen R, Abebe A, Choge SK, Nigatu L, Mbaabu PR, Shiferaw H, Allan E (2019) Direct and indirect effects of invasive species: biodiversity loss is a major mechanism by which an invasive tree affects ecosystem functioning. Journal of Ecology 107: 2660–2672. https://doi.org/10.1111/1365-2745.13268

Lorentz KA, Minogue PJ (2015) Potential invasiveness for *Eucalyptus* species in Florida. Invasive Plant Science and Management 8: 90–97. https://doi.org/10.1614/IPSM-D-14-00030.1

Lugo AE (1997) The apparent paradox of reestablishing species richness on degraded lands with tree monocultures. Forest Ecology and Management 99: 9–19. https://doi.org/10.1016/S0378-1127(97)00191-6

Lugo AE (2004) The outcome of alien tree invasions in Puerto Rico. Frontiers in Ecology and the Environment 2: 265–273. https://doi.org/10.1890/1540-9295(2004)002[0265:TOOATI]2.0.CO;2

Lugo AE (2015) Forestry in the Anthropocene. Science 349: 771. https://doi.org/10.1126/science.aad2208

Magessa K, Wynne-Jones S, Hockley N (2020) Does Tanzanian participatory forest management policy achieve its governance objectives? Forest Policy and Economics 111: 102077. https://doi.org/10.1016/j.forpol.2019.102077

Marchante E, Marchante H, Morais M, Freitas H (2011) Combining methodologies to increase public awareness about invasive alien plants in Portugal. In: Brunel S, Uludag A, Fernandez-Galiano E, Brundu G (Eds) 2nd International Workshop on Invasive Plants in Mediterranean Type Regions of the World, Trabzon, Turkey, 227–239.

Marzano M, Allen W, Haight RG, Holmes TP, Keskitalo ECH, Langer ERL, Shadbolt M, Urquhart J, Dandy N (2017) The role of the social sciences and economics in understanding and informing tree biosecurity policy and planning: a global summary and synthesis. Biological Invasions 19: 3317–3332. https://doi.org/10.1007/s10530-017-1503-4

Masiero M, Secco L, Pettenella D, Brotto L (2015) Standards and guidelines for forest plantation management: A global comparative study. Forest Policy and Economics 53: 29–44. https://doi.org/10.1016/j.forpol.2014.12.008

Maundu P, Kibet S, Morimoto Y, Imbumi M, Adeka R (2009) Impact of *Prosopis juliflora* on Kenya's semi-arid and arid ecosystems and local livelihoods. Biodiversity 10: 33–50. https://doi.org/10.1080/14888386.2009.9712842

Mbaabu PR, Ng W-T, Schaffner U, Gichaba M, Olago D, Choge S, Oriaso S, Eckert S (2019) Spatial evolution of *Prosopis* invasion and its effects on LULC and livelihoods in Baringo, Kenya. Remote Sensing 11: 1217. https://doi.org/10.3390/rs11101217

McCormick N, Howard G (2013) Beating back biofuel crop invasions: guidelines on managing the invasive risk of biofuel developments. Selected papers from World Renewable Energy Congress – XI 49: 263–266. https://doi.org/10.1016/j.renene.2012.01.018

McGregor KF, Watt MS, Hulme PE, Duncan RP (2012) How robust is the Australian Weed Risk Assessment protocol? A test using pine invasions in the Northern and Southern hemispheres. Biological Invasions 14: 987–998. https://doi.org/10.1007/s10530-011-0133-5

McLean P, Gallien L, Wilson JRU, Gaertner M, Richardson DM (2017) Small urban centres as launching sites for plant invasions in natural areas: insights from South Africa. Biological Invasions 19: 3541–3555. https://doi.org/10.1007/s10530-017-1600-4

Mehrabian AR, Sayadi S, Majidi Kuhbenani M, Hashemi Yeganeh V, Abdoljabari M (2020) Priorities for conservation of endemic trees and shrubs of Iran: Important Plant Areas (IPAs) and Alliance for Zero Extinction (AZE) in SW Asia. Journal of Asia-Pacific Biodiversity 13: 295–305. https://doi.org/10.1016/j.japb.2019.09.010

Mitchell RJ, Campbell CD, Chapman SJ, Osler GHR, Vanbergen AJ, Ross LC, Cameron CM, Cole L (2007) The cascading effects of birch on heather moorland: a test for the top-down control of an ecosystem engineer. Journal of Ecology 95: 540–554. https://doi.org/10.1111/j.1365-2745.2007.01227.x

Mohammed AK (2013) Civic engagement in public policy making: fad or reality in Ghana? Politics & Policy 41: 117–152. https://doi.org/10.1111/polp.12003

Morris JL, Cottrell S, Fettig CJ, Hansen WD, Sherriff RL, Carter VA, Clear JL, Clement J, DeRose RJ, Hicke JA, Higuera PE, Mattor KM, Seddon AWR, Seppä HT, Stednick JD, Seybold SJ (2017) Managing bark beetle impacts on ecosystems and society: priority questions to motivate future research. Journal of Applied Ecology 54: 750–760. https://doi.org/10.1111/1365-2664.12782

Moss T, Monstadt J (2008) Restoring FLoodplains in Europe: Policy contexts and project experiences. IWA Publishing. https://doi.org/10.2166/9781780401966

Motta R, Nola P, Berretti R (2009) The rise and fall of the black locust (*Robinia pseudoacacia* L.) in the "Siro Negri" Forest Reserve (Lombardy, Italy): lessons learned and future uncertainties. Annals of Forest Science 66: 410. https://doi.org/10.1051/forest/2009012

Mullah CJA, Klanderud K, Totland Ø, Odee D (2014) Community invasibility and invasion by non-native Fraxinus pennsylvanica trees in a degraded tropical forest. Biological Invasions 16: 2747–2755. https://doi.org/10.1007/s10530-014-0701-6

Nazir N, Farooq A, Ahmad Jan S, Ahmad A (2019) A system dynamics model for billion trees tsunami afforestation project of Khyber Pakhtunkhwa in Pakistan: Model application to afforestation activities. Journal of Mountain Science 16: 2640–2653. https://doi.org/10.1007/s11629-018-5076-1

Neary DG (2013) Best management practices for forest bioenergy programs. Wiley Interdisciplinary Reviews: Energy and Environment 2: 614–632. https://doi.org/10.1002/wene.77

Nereu M, Silva JS, Deus E, Nunes M, Potts B (2019) The effect of management operations on the demography of *Eucalyptus globulus* seedlings. Forest Ecology and Management 453: 117630. https://doi.org/10.1016/j.foreco.2019.117630

Nielsen LR, McKinney LV, Hietala AM, Kjær ED (2017) The susceptibility of Asian, European and North American *Fraxinus* species to the ash dieback pathogen *Hymenoscyphus frax-*

ineus reflects their phylogenetic history. European Journal of Forest Research 136: 59–73. https://doi.org/10.1007/s10342-016-1009-0

Novoa A, Shackleton R, Canavan S, Cybèle C, Davies SJ, Dehnen-Schmutz K, Fried J, Gaertner M, Geerts S, Griffiths CL, Kaplan H, Kumschick S, Le Maitre DC, Measey GJ, Nunes AL, Richardson DM, Robinson TB, Touza J, Wilson JRU (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 MA, Chiuffo MC, Torres A, Paul T, Dimarco RD, Raal P, Policelli N, Moyano J, García RA, van Wilgen BW, Pauchard A, Richardson DM (2017) Ecology and management of invasive Pinaceae around the world: progress and challenges. Biological Invasions 19: 3099–3120. https://doi.org/10.1007/s10530-017-1483-4

Ormsby M, Brenton-Rule E (2017) A review of global instruments to combat invasive alien species in forestry. Biological Invasions 19: 3355–3364. https://doi.org/10.1007/s10530-017-1426-0

Packer JG, Meyerson LA, Richardson DM, Brundu G, Allen WJ, Bhattarai GP, Brix H, Canavan S, Castiglione S, Cicatelli A, Čuda J, Cronin JT, Eller F, Guarino F, Guo W-H, Guo W-Y, Guo X, Hierro JL, Lambertini C, Liu J, Lozano V, Mozdzer TJ, Skálová H, Villarreal D, Wang R-Q, Pyšek P (2017) Global networks for invasion science: benefits, challenges and guidelines. Biological Invasions 19: 1081–1096. https://doi.org/10.1007/s10530-016-1302-3

Pandit MK, Pocock MJO, Kunin WE (2011) Ploidy influences rarity and invasiveness in plants. Journal of Ecology 99: 1108–1115. https://doi.org/10.1111/j.1365-2745.2011.01838.x

Papaioannou A, Chatzistathis T, Papaioannou E, Papadopoulos G (2016) *Robinia pseudoacacia* as a valuable invasive species for the restoration of degraded croplands. CATENA 137: 310–317. https://doi.org/10.1016/j.catena.2015.09.019

Paritsis J, Landesmann J, Kitzberger T, Tiribelli F, Sasal Y, Quintero C, Dimarco R, Barrios-García M, Iglesias A, Diez J, Sarasola M, Nuñez M (2018) Pine plantations and invasion alter fuel structure and potential fire behavior in a Patagonian Forest-Steppe ecotone. Forests 9: 117. https://doi.org/10.3390/f9030117

Paul TSH, SCION (2015) Guidelines for the Use of the Decision Support System Calculating Wilding Spread Risk from new Plantings. New Zealand Forest Research Institute Limited, Scion, Rotorua, 22 pp. https://www.wildingconifers.org.nz/assets/wilding-conifer-Guidelines-for-using-the-DSS-for-new-forest-plantings.pdf

Pedlar JH, McKenney DW, Aubin I, Beardmore T, Beaulieu J, Iverson L, O'Neill GA, Winder RS, Ste-Marie C (2012) Placing forestry in the assisted migration debate. BioScience 62: 835–842. https://doi.org/10.1525/bio.2012.62.9.10

Peltzer DA, Bellingham PJ, Dickie IA, Hulme PE (2015) Commercial forests: native advantage. Science 349: 1176. https://doi.org/10.1126/science.349.6253.1176-a

Pergl J, Sádlo J, Petrusek A, Laštůvka Z, Musil J, Perglová I, Šanda R, Šefrová H, Šíma J, Vohralík V, Pyšek P (2016) Black, Grey and Watch Lists of alien species in the Czech Republic based on environmental impacts and management strategy. NeoBiota 28: 1–37. https://doi.org/10.3897/neobiota.28.4824

Peterson St-Laurent G, Hagerman S, Kozak R (2018) What risks matter? Public views about assisted migration and other climate-adaptive reforestation strategies. Climatic Change 151: 573–587. https://doi.org/10.1007/s10584-018-2310-3

Petitpierre B, Kueffer C, Broennimann O, Randin C, Daehler C, Guisan A (2012) Climatic niche shifts are rare among terrestrial plant invaders. Science 335: 1344–1348. https://doi.org/10.1126/science.1215933

Pheloung PC, Williams PA, Halloy SR (1999) A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. Journal of Environmental Management 57: 239–251. https://doi.org/10.1006/jema.1999.0297

Pineo H, Zimmermann N, Davies M (2020) Integrating health into the complex urban planning policy and decision-making context: a systems thinking analysis. Palgrave Communications 6: 1–21. https://doi.org/10.1057/s41599-020-0398-3

Pinto S, Melo F, Tabarelli M, Padovesi A, Mesquita C, de Mattos Scaramuzza C, Castro P, Carrascosa H, Calmon M, Rodrigues R, César R, Brancalion P (2014) Governing and delivering a biome-wide restoration initiative: the case of Atlantic Forest Restoration Pact in Brazil. Forests 5: 2212–2229. https://doi.org/10.3390/f5092212

Pirard R, Petit H, Baral H (2017) Local impacts of industrial tree plantations: an empirical analysis in Indonesia across plantation types. Land Use Policy 60: 242–253. https://doi.org/10.1016/j.landusepol.2016.10.038

Podrázský V, Vacek Z, Vacek S, Vítámvás J, Gallo J, Prokůpková A, D'Andrea G (2020) Production potential and structural variability of pine stands in the Czech Republic: Scots pine (*Pinus sylvestris* L.) vs. introduced pines – case study and problem review. Journal of Forest Science 66: 197–207. https://doi.org/10.17221/42/2020-JFS

Popkin G (2019) The forest question. Nature 565: 280–282. https://doi.org/10.1038/d41586-019-00122-z

Porazinska DL, Pratt PD, Glblin-Davis RM (2007) Consequences of *Melaleuca quinquenervia* Invasion on Soil Nematodes in the Florida Everglades. Journal of Nematology 39: 305–312.

Potgieter LJ, Gaertner M, Kueffer C, Larson BMH, Livingstone SW, O'Farrell PJ, Richardson DM (2017) Alien plants as mediators of ecosystem services and disservices in urban systems: a global review. Biological Invasions 19: 3571–3588. https://doi.org/10.1007/s10530-017-1589-8

Pötzelsberger E, Lapin K, Brundu G, Adriaens T, Andonovski V, Andrašev S, Bastien J-C, Brus R, Čurović M, Čurović Ž, Cvjetković B, Đodan M, Domingo-Santos JM, Gazda A, Henin J-M, Hernea C, Karlsson B, Keča L, Keren S, Keserű Z, Konstantara T, Kroon J, La Porta N, Lavnyy V, Lazdina D, Lukjanova A, Maaten T, Madsen P, Mandjukovski D, Marín Pageo FJ, Marozas V, Martinik A, Mason WL, Mohren F, Monteverdi MC, Neophytou C, Neville P, Nicolescu V-N, Nygaard PH, Orazio C, Parpan T, Perić S, Petkova K, Popov EB, Power M, Rédei K, Rousi M, Silva JS, Sivacioğlu A, Socratous M, Straigytė L, Urban J, Vandekerkhove K, Wąsik R, Westergren M, Wohlgemuth T, Ylioja T, Hasenauer H (2020) Mapping the patchy legislative landscape of non-native tree species in Europe. Forestry: An International Journal of Forest Research 93: 567–586. https://doi.org/10.1093/forestry/cpaa009

Pyšek P, Richardson DM (2007) Traits associated with invasiveness in alien plants: where do we stand? In: Nentwig W (Ed.) Biological Invasions. Springer, Berlin, 97–125. https://doi.org/10.1007/978-3-540-36920-2_7

Radtke A, Ambraß S, Zerbe S, Tonon G, Fontana V, Ammer C (2013) Traditional coppice forest management drives the invasion of *Ailanthus altissima* and *Robinia pseudoacacia* into deciduous forests. Forest Ecology and Management 291: 308–317. https://doi.org/10.1016/j.foreco.2012.11.022

Raum S (2018) A framework for integrating systematic stakeholder analysis in ecosystem services research: stakeholder mapping for forest ecosystem services in the UK. Ecosystem Services 29: 170–184. https://doi.org/10.1016/j.ecoser.2018.01.001

Reichard SH, Hamilton CW (1997) Predicting invasions of woody plants introduced into North America. Conservation Biology 11: 193–203. https://doi.org/10.1046/j.1523-1739.1997.95473.x

Rejmánek M (1996) A theory of seed plant invasiveness: the first sketch. Invasion Biology 78: 171–181. https://doi.org/10.1016/0006-3207(96)00026-2

Rejmánek M, Richardson DM (2013) Trees and shrubs as invasive alien species – 2013 update of the global database. Diversity and Distributions 19: 1093–1094. https://doi.org/10.1111/ddi.12075

Reyer CPO, Silveyra Gonzalez R, Dolos K, Hartig F, Hauf Y, Noack M, Lasch-Born P, Rötzer T, Pretzsch H, Mesenburg H, Fleck S, Wagner M, Bolte A, Sanders TGM, Kolari P, Mäkelä A, Vesala T, Mammarella I, Pumpanen J, Collalti A, Trotta C, Matteucci G, D'Andrea E, Foltýnová L, Krejza J, Ibrom A, Pilegaard K, Loustau D, Bonnefond J-M, Berbigier P, Picart D, Lafont S, Dietze M, Cameron D, Vieno M, Tian H, Palacios-Orueta A, Cicuendez V, Recuero L, Wiese K, Büchner M, Lange S, Volkholz J, Kim H, Weedon GP, Sheffield J, Vega del Valle I, Suckow F, Horemans JA, Martel S, Bohn F, Steinkamp J, Chikalanov A, Mahnken M, Gutsch M, Frieler K (2019) The PROFOUND database for evaluating vegetation models and simulating climate impacts on forests. Earth System Science Data Discussions 2019: 1–47. https://doi.org/10.5194/essd-2019-220

Ribeiro H, Oliveira M, Ribeiro N, Cruz A, Ferreira A, Machado H, Reis A, Abreu I (2009) Pollen allergenic potential nature of some trees species: a multidisciplinary approach using aerobiological, immunochemical and hospital admissions data. Environmental Research 109: 328–333. https://doi.org/10.1016/j.envres.2008.11.008

Richardson DM (1998) Forestry trees as invasive aliens. Conservation Biology 12: 18–26. https://doi.org/10.1111/j.1523-1739.1998.96392.x

Richardson DM (2011) Forestry and Agroforestry. Encyclopedia of Biological Invasions. University of California Press, Berkeley and Los Angeles, 241–248.

Richardson DM, Rejmánek M (2011) Trees and shrubs as invasive alien species – a global review. Diversity and Distributions 17: 788–809. https://doi.org/10.1111/j.1472-4642.2011.00782.x

Richardson DM, Le Roux JJ, Wilson JR (2015) Australian acacias as invasive species: lessons to be learnt from regions with long planting histories. Southern Forests: a Journal of Forest Science 77: 31–39. https://doi.org/10.2989/20702620.2014.999305

Richardson DM, Hui C, Nuñez MA, Pauchard A (2014) Tree invasions: patterns, processes, challenges and opportunities. Biological Invasions 16: 473–481. https://doi.org/10.1007/s10530-013-0606-9

Richardson DM, Pyšek P, Rejmánek M, Barbour MG, Panetta FD, West CJ (2000) Naturalization and invasion of alien plants: concepts and definitions. Diversity and Distributions 6: 93–107. https://doi.org/10.1046/j.1472-4642.2000.00083.x

Richardson DM, Hellmann JJ, McLachlan JS, Sax DF, Schwartz MW, Gonzalez P, Brennan EJ, Camacho A, Root TL, Sala OE, Schneider SH, Ashe DM, Clark JR, Early R, Etterson JR, Fielder ED, Gill JL, Minteer BA, Polasky S, Safford HD, Thompson AR, Vellend M (2009) Multidimensional evaluation of managed relocation. Proceedings of the National Academy of Sciences of the USA 106: 9721–9724. https://doi.org/10.1073/pnas.0902327106

Riley C, Perry K, Ard K, Gardiner M (2018) Asset or liability? ecological and sociological trade-offs of urban spontaneous vegetation on vacant land in shrinking cities. Sustainability 10: 2139. https://doi.org/10.3390/su10072139

Roques A, Fan J, Courtial B, Zhang Y, Yart A, Auger-Rozenberg M-A, Denux O, Kenis M, Baker R, Sun J (2015) Planting sentinel European trees in Eastern Asia as a novel method to identify potential insect pest invaders. PLoS ONE 10: e0120864. https://doi.org/10.1371/journal.pone.0120864

Rotherham ID, Lambert RA (2012) Invasive and Introduced Plants and Animals: Human Perceptions, Attitudes and Approaches to Management. Routledge, London and Washington. https://doi.org/10.4324/9780203525753

Rouget M, Robertson MP, Wilson JRU, Hui C, Essl F, Renteria JL, Richardson DM (2016) Invasion debt – quantifying future biological invasions. Diversity and Distributions 22: 445–456. https://doi.org/10.1111/ddi.12408

Roy HE, Peyton J, Aldridge DC, Bantock T, Blackburn TM, Britton R, Clark P, Cook E, Dehnen-Schmutz K, Dines T, Dobson M, Edwards F, Harrower C, Harvey MC, Minchin D, Noble DG, Parrott D, Pocock MJO, Preston CD, Roy S, Salisbury A, Schönrogge K, Sewell J, Shaw RH, Stebbing P, Stewart AJA, Walker KJ (2014) Horizon scanning for invasive alien species with the potential to threaten biodiversity in Great Britain. Global Change Biology 20: 3859–3871. https://doi.org/10.1111/gcb.12603

Ruiz-Benito P, Vacchiano G, Lines ER, Reyer CPO, Ratcliffe S, Morin X, Hartig F, Mäkelä A, Yousefpour R, Chaves JE, Palacios-Orueta A, Benito-Garzón M, Morales-Molino C, Camarero JJ, Jump AS, Kattge J, Lehtonen A, Ibrom A, Owen HJF, Zavala MA (2020) Available and missing data to model impact of climate change on European forests. Ecological Modelling 416: 108870. https://doi.org/10.1016/j.ecolmodel.2019.108870

Rundel PW, Dickie IA, Richardson DM (2014) Tree invasions into treeless areas: mechanisms and ecosystem processes. Biological Invasions 16: 663–675. https://doi.org/10.1007/s10530-013-0614-9

Sádlo J, Vítková M, Pergl J, Pyšek P (2017) Towards site-specific management of invasive alien trees based on the assessment of their impacts: the case of *Robinia pseudoacacia*. NeoBiota 35: 1–34. https://doi.org/10.3897/neobiota.35.11909

dos Santos AR, da Rocha CFD, Bergallo HG (2010) Native and exotic species in the urban landscape of the city of Rio de Janeiro, Brazil: density, richness, and arboreal deficit. Urban Ecosystems 13: 209–222. https://doi.org/10.1007/s11252-009-0113-z

Schmidt LH (2007) Tropical Forest Seed. Springer, Cham. https://doi.org/10.1007/978-3-540-68864-8

Schreck Reis C, Marchante H, Freitas H, Marchante E (2013) Public Perception of Invasive Plant Species: Assessing the impact of workshop activities to promote young students' awareness. International Journal of Science Education 35: 690–712. https://doi.org/10.1080/09500693.2011.610379

Schwartz MW, Hellmann JJ, McLachlan JM, Sax DF, Borevitz JO, Brennan J, Camacho AE, Ceballos G, Clark JR, Doremus H, Early R, Etterson JR, Fielder D, Gill JL, Gonzalez P, Green N, Hannah L, Jamieson DW, Javeline D, Minteer BA, Odenbaugh J, Polasky S, Richardson DM, Root TL, Safford HD, Sala O, Schneider SH, Thompson AR, Williams JW, Vellend M, Vitt P, Zellmer S (2012) Managed Relocation: integrating the scientific, regulatory, and ethical challenges. BioScience 62: 732–743. https://doi.org/10.1525/bio.2012.62.8.6

Seidl R, Thom D, Kautz M, Martin-Benito D, Peltoniemi M, Vacchiano G, Wild J, Ascoli D, Petr M, Honkaniemi J, Lexer MJ, Trotsiuk V, Mairota P, Svoboda M, Fabrika M, Nagel TA, Reyer CPO (2017) Forest disturbances under climate change. Nature Climate Change 7: 395–402. https://doi.org/10.1038/nclimate3303

Serra-Diaz JM, Enquist BJ, Maitner B, Merow C, Svenning J-C (2018) Big data of tree species distributions: how big and how good? Forest Ecosystems 4: 1–30. https://doi.org/10.1186/s40663-017-0120-0

Seymour F, Harris NL (2019) Reducing tropical deforestation. Science 365: 756–757. https://doi.org/10.1126/science.aax8546

Shackleton RT, Adriaens T, Brundu G, Dehnen-Schmutz K, Estévez RA, Fried J, Larson BMH, Liu S, Marchante E, Marchante H, Moshobane MC, Novoa A, Reed M, Richardson DM (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

Sharma S, McKirdy S, Macbeth F (2014) The biosecurity continuum and trade: Tools for post-border biosecurity. The Handbook of Plant Biosecurity. Springer, 189–206. https://doi.org/10.1007/978-94-007-7365-3_7

Shine C (2007) Invasive species in an international context: IPPC, CBD, European Strategy on Invasive Alien Species and other legal instruments. EPPO Bulletin 37: 103–113. https://doi.org/10.1111/j.1365-2338.2007.01087.x

Sigaud P (2000) The need for an international framework for the conservation and sustainable utilization of forest genetic resources. In: Mátyás C (Eds) Forest Genetics and Sustainability. Springer, Dordrecht, 217–222. https://doi.org/10.1007/978-94-017-1576-8_20

Silva PHM da, Bouillet J-P, de Paula RC (2016) Assessing the invasive potential of commercial *Eucalyptus* species in Brazil: germination and early establishment. Forest Ecology and Management 374: 129–135. https://doi.org/10.1016/j.foreco.2016.05.007

Silveira FAO, Arruda AJ, Bond W, Durigan G, Fidelis A, Kirkman K, Oliveira RS, Overbeck GE, Sansevero JBB, Siebert F, Siebert SJ, Young TP, Buisson E (2020) Myth-busting tropical grassy biome restoration. Restoration Ecology, in press. https://doi.org/10.1111/rec.13202

Sims L, Tjosvold S, Chambers D, Garbelotto M (2019) Control of *Phytophthora* species in plant stock for habitat restoration through best management practices. Plant Pathology 68: 196–204. https://doi.org/10.1111/ppa.12933

Sitzia T, Campagnaro T, Dainese M, Cierjacks A (2012) Plant species diversity in alien black locust stands: a paired comparison with native stands across a north-Mediterranean range expansion. Forest Ecology and Management 285: 85–91. https://doi.org/10.1016/j.foreco.2012.08.016

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: 1–7. https://doi.org/10.1007/s10530-015-0999-8

Sjöman H, Morgenroth J, Sjöman JD, Sæbø A, Kowarik I (2016) Diversification of the urban forest-can we afford to exclude exotic tree species? Urban Forestry & Urban Greening 18: 237–241. https://doi.org/10.1016/j.ufug.2016.06.011

Sladonja B, Sušek M, Guillermic J (2015) Review on invasive tree of heaven (*Ailanthus altissima* (Mill.) Swingle) conflicting values: assessment of its ecosystem services and potential biological threat. Environmental Management 56: 1009–1034. https://doi.org/10.1007/s00267-015-0546-5

Souza-Alonso P, Rodríguez J, González L, Lorenzo P (2017) Here to stay. Recent advances and perspectives about *Acacia* invasion in Mediterranean areas. Annals of Forest Science 74: 1–55. https://doi.org/10.1007/s13595-017-0651-0

Spellerberg IF, Given DR (2008) Trees in urban and city environments: a review of the selection criteria with particular reference to nature conservation in New Zealand cities. Landscape Review 12: 19–31.

Stanturf JA, Palik BJ, Dumroese RK (2014) Contemporary forest restoration: a review emphasizing function. Forest Ecology and Management 331: 292–323. https://doi.org/10.1016/j.foreco.2014.07.029

Starfinger U, Kowarik I, Rode M, Schepker H (2003) From desirable ornamental plant to pest to accepted addition to the flora? – the perception of an alien tree species through the centuries. Biological Invasions 5: 323–335. https://doi.org/10.1023/B:BINV.0000005573.14800.07

Stokes KE, O°FNeill KP, Montgomery WI, Dick JTA, Maggs CA, McDonald RA (2006) The importance of stakeholder engagement in invasive species management: a cross-jurisdictional perspective in Ireland. Biodiversity & Conservation 15: 2829–2852. https://doi.org/10.1007/s10531-005-3137-6

Stupak I, Lattimore B, Titus BD, Tattersall Smith C (2011) Criteria and indicators for sustainable forest fuel production and harvesting: a review of current standards for sustainable forest management. Proceedings of a Workshop of IEA Bioenergy Task 31 on 'Sustainable Forestry Systems for Bioenergy: Integration, Innovation and Information' 35: 3287–3308. https://doi.org/10.1016/j.biombioe.2010.11.032

Sturgess P, Atkinson D (1993) The clear-felling of sand-dune plantations: Soil and vegetational processes in habitat restoration. Biological Conservation 66: 171–183. https://doi.org/10.1016/0006-3207(93)90003-J

Sudirman, Wiliam D, McGrath S (2004) Public Participation in Local Forestry Policy-making after Decentralization. Center for International Forestry Research. www.jstor.org/stable/resrep02003 [June 4, 2020]

Sujii PS, Schwarcz KD, Grando C, de Aguiar Silvestre E, Mori GM, Brancalion PHS, Zucchi MI (2017) Recovery of genetic diversity levels of a Neotropical tree in Atlantic Forest restoration plantations. Biological Conservation 211: 110–116. https://doi.org/10.1016/j.biocon.2017.05.006

Swallow B, Mwangi E (2008) *Prosopis juliflora* invasion and rural livelihoods in the Lake Baringo area of Kenya. Conservation and Society 6: 1–130. https://doi.org/10.4103/0972-4923.49207

Szitár K, Ónodi G, Somay L, Pándi I, Kucs P, Kröel-Dulay G (2014) Recovery of inland sand dune grasslands following the removal of alien pine plantation. Biological Conservation 171: 52–60. https://doi.org/10.1016/j.biocon.2014.01.021

Tavares A, Beiroz W, Fialho A, Frazão F, Macedo R, Louzada J, Audino L (2019) *Eucalyptus* plantations as hybrid ecosystems: implications for species conservation in the Brazilian Atlantic Forest. Forest Ecology and Management 433: 131–139. https://doi.org/10.1016/j.foreco.2018.10.063

Temperton VM, Buchmann N, Buisson E, Durigan G, Kazmierczak Ł, Perring MP, de Sá Dechoum M, Veldman JW, Overbeck GE (2019) Step back from the forest and step up to the Bonn Challenge: how a broad ecological perspective can promote successful landscape restoration. Restoration Ecology 27: 705–719. https://doi.org/10.1111/rec.12989

The One Earth editorial team (2020) Trees do not make a forest. One Earth 2: 385–386. https://doi.org/10.1016/j.oneear.2020.05.005

Thompson M, Lyons A, Kumarasinghe L, Peck DR, Kong G, Shattuck S, La Salle J (2011) Remote microscopy: a success story in Australian and New Zealand plant biosecurity. Australian Journal of Entomology 50: 1–6. https://doi.org/10.1111/j.1440-6055.2010.00803.x

Trunov AA (2017) Deforestation in Russia and its contribution to the anthropogenic emission of carbon dioxide in 1990–2013. Russian Meteorology and Hydrology 42: 529–537. https://doi.org/10.3103/S1068373917080064

Tsiamis K, Gervasini E, D'Amico F, Deriu I, Katsanevakis S, Crocetta F, Zenetos A, Arianoutsou M, Backeljau T, Bariche M, Bazos I, Bertaccini A, Brundu G, Carrete M, Çinar M, Curto G, Faasse M, Justine J-L, Király G, Langer M, Levitt Y, Panov V, Piraino S, Rabitsch W, Roques A, Scalera R, Shenkar N, Sîrbu I, Tricarico E, Vannini A, Vøllestad LA, Zikos A, Cardoso AC (2016) The EASIN Editorial Board: quality assurance, exchange and sharing of alien species information in Europe. Management of Biological Invasions 7: 321–328. https://doi.org/10.3391/mbi.2016.7.4.02

USDA (2012) Non native Invasive Species Best Management Practices – Guidance for the U.S. Forest Service Eastern Region, 282 pp. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5412628.pdf

Vanbeveren SPP, Ceulemans R (2019) Biodiversity in short-rotation coppice. Renewable and Sustainable Energy Reviews 111: 34–43. https://doi.org/10.1016/j.rser.2019.05.012

Vaz AS, Honrado JP, 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

Vaz AS, Kueffer C, Kull CA, Richardson DM, Vicente JR, Kühn I, Schröter M, Hauck J, Bonn A, Honrado JP (2017) Integrating ecosystem services and disservices: insights from plant invasions. Ecosystem Services 23: 94–107. https://doi.org/10.1016/j.ecoser.2016.11.017

Veenvliet JK, Veenvliet P, de Groot M, Kutnar L (2019) A Field Guide to Invasive Alien Species in European Forests. Institute Symbiosis, and The Silva Slovenica Publishing Centre, Slovenian Forestry Institute, 2017 pp. https://neobiota.lu/field-guide-to-invasive-alien-species-in-european-forests/

Vidal C, Alberdi I, Redmond J, Vestman M, Lanz A, Schadauer K (2016) The role of European National Forest Inventories for international forestry reporting. Annals of Forest Science 73: 793–806. https://doi.org/10.1007/s13595-016-0545-6

Visser V, Langdon B, Pauchard A, Richardson DM (2014) Unlocking the potential of Google Earth as a tool in invasion science. Biological Invasions 16: 513–534. https://doi.org/10.1007/s10530-013-0604-y

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

Vítková M, Sádlo J, Roleček J, Petřík P, Sitzia T, Müllerová J, Pyšek P (2020) *Robinia pseudoacacia*-dominated vegetation types of Southern Europe: species composition, history, distribution and management. Science of The Total Environment 707: 134857. https://doi.org/10.1016/j.scitotenv.2019.134857

Wang F, Zhu W, Zou B, Neher DA, Fu S, Xia H, Li Z (2013) Seedling growth and soil nutrient availability in exotic and native tree species: implications for afforestation in southern China. Plant and Soil 364: 207–218. https://doi.org/10.1007/s11104-012-1353-x

Weih M (2008) Short rotation forestry (SRF) on agricultural land and its possibilities for sustainable energy supply. Nordic Council of Ministers, 66 pp.

Whittet R, Cottrell J, Cavers S, Pecurul M, Ennos R (2016) Supplying trees in an era of environmental uncertainty: Identifying challenges faced by the forest nursery sector in Great Britain. Land Use Policy 58: 415–426. https://doi.org/10.1016/j.landusepol.2016.07.027

van Wilgen BW, Richardson DM (2012) Three centuries of managing introduced conifers in South Africa: benefits, impacts, changing perceptions and conflict resolution. Journal of Environmental Management 106: 56–68. https://doi.org/10.1016/j.jenvman.2012.03.052

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

van Wilgen BW, Measey J, Richardson DM, Wilson JR, Zengeya TA (2020) Biological Invasions in South Africa: An overview. In: van Wilgen BW, Measey J, Richardson DM, Wilson JR, Zengeya TA (Eds) Biological Invasions in South Africa. Springer International Publishing, Cham, 3–31. https://doi.org/10.1007/978-3-030-32394-3_1

Wilson JRU, Caplat P, Dickie IA, Hui C, Maxwell BD, Nuñez MA, Pauchard A, Rejmánek M, Richardson DM, Robertson MP, Spear D, Webber BL, van Wilgen BW, Zenni RD (2014) A standardized set of metrics to assess and monitor tree invasions. Biological Invasions 16: 535–551. https://doi.org/10.1007/s10530-013-0605-x

Wingfield MJ, Brockerhoff EG, Wingfield BD, Slippers B (2015) Planted forest health: the need for a global strategy. Science 349: 832–836. https://doi.org/10.1126/science.aac6674

Woodford DJ, Richardson DM, MacIsaac HJ, Mandrak NE, van Wilgen BW, Wilson JRU, Weyl OLF (2016) Confronting the wicked problem of managing biological invasions. NeoBiota 31: 63–86. https://doi.org/10.3897/neobiota.31.10038

Zavaleta E (2000) The economic value of controlling an invasive shrub. AMBIO: A Journal of the Human Environment 29: 462–467. https://doi.org/10.1579/0044-7447-29.8.462

Zhang Q, Jia X, Shao M, Zhang C, Li X, Ma C (2018) Sap flow of black locust in response to short-term drought in southern Loess Plateau of China. Scientific Reports 8: 6222. https://doi.org/10.1038/s41598-018-24669-5

Zhou X, Zhu H, Wen Y, Goodale UM, Zhu Y, Yu S, Li C, Li X (2020) Intensive management and declines in soil nutrients lead to serious exotic plant invasion in *Eucalyptus* plantations under successive short-rotation regimes. Land Degradation & Development 31: 297–310. https://doi.org/10.1002/ldr.3449

Ziller SR, de Sá Dechoum M, Dudeque Zenni R (2019) Predicting invasion risk of 16 species of eucalypts using a risk assessment protocol developed for Brazil. Austral Ecology 44: 28–35. https://doi.org/10.1111/aec.12649

Supplementary material 1

Global guidelines for the sustainable use of non-native trees to prevent tree invasions and mitigate their negative impacts (GG-NNTs) Background information (Annex to the GG-NNTs)

Authors: Giuseppe Brundu, Aníbal Pauchard, Petr Pyšek, Jan Pergl, Anja M. Bindewald, Antonio Brunori, Susan Canavan, Thomas Campagnaro, Laura Celesti-Grapow, Michele de Sá Dechoum, Jean-Marc Dufour-Dror, Franz Essl, S. Luke Flory, Piero Genovesi, Francesco Guarino, Liu Guangzhe, Philip E. Hulme, Heinke Jäger, Christopher J. Kettle, Frank Krumm, Barbara Langdon, Katharina Lapin, Vanessa Lozano, Johannes J. Le Roux, Ana Novoa, Martin A. Nuñez, Annabel J. Porté, Joaquim S. Silva, Urs Schaffner, Tommaso Sitzia, Rob Tanner, Ntakadzeni Tshidada, Michaela Vítková, Marjana Westergren, John R. U. Wilson, David M. Richardson

Data type: additional materials

Explanation note: Terms and definitions, Acronyms, and additional Tables: Non-native tree species in planted forests and for other uses: historical and recent pathways of introduction; Main types of negative impacts of INNTs (after Richardson et al. 2000); Major international initiatives and legislation pertaining to invasive alien species and INNTs.

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