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CODE OF CONDUCT FOR PLANTED FOREST AND INVASIVE ALIEN TREES

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1. RATIONALE AND AIMS OF THE CODE OF CONDUCT

This Code of Conduct is addressed to all relevant stakeholders and decision makers in the 47 Member States of the Council of Europe. It is intended to provide guidance for sustainable use of **alien**[1] (non-native, exotic, introduced) tree species in **planted forests**[2] and to reduce the negative impacts that might originate from the unregulated use of **invasive**[3] **alien** trees.

Well-managed planted forests of alien tree species can be useful in providing various forest goods and services and helping to reduce the pressure on natural forests (FAO 2015b). Globally, natural forest area is decreasing and the area of planted forests is increasing. Planted forest area increased by over 110 million ha since 1990 and accounts for 7 percent of the world's forest area (FAO 2015b). Although there are marked differences between and within regions, between 18 % and 19 % of planted forests have been estimated to comprise alien tree species (Payn et al. 2015; FAO 2015a, 2015b).

However, a small number of alien forestry trees are invasive or might become invasive – i.e. they spread from planting sites into adjoining areas, and sometimes cause substantial damage. The challenge is to manage existing and future planted forests of alien trees to maximise current benefits, while minimising risks and negative impacts, without compromising future benefits and land uses.

The fourteen principles of the Code of Conduct are clustered in five groups:

(1) Awareness;

(2) Prevention & Containment;

(3) Early Detection & Rapid Response;

(4) Outreach;

(5) Forward Planning.

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[1] In the context of the present Code of Conduct the terms alien, non-native, exotic and introduced (tree) are considered as equivalent. In accordance with the CBD definition, the term alien has exclusively a biogeographical meaning, i.e. it refers to a species, subspecies or lower taxon, introduced outside its natural past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce. As such, the term alien does not include any negative evaluation of the species. Only a small percentage of all the alien species are, or may become after some time, invasive alien species (COP 6 Decision VI/23 "Alien species that threaten ecosystems, habitats or species"). Importantly, an alien species is "introduced outside its natural past or present distribution" deliberately or accidentally by man. The Recommendation No. 142 (2009) of the Standing Committee (Convention on the Conservation of European Wildlife and Natural Habitats), adopted on 26 November 2009, interpreting the CBD definition of invasive alien species to take into account climate change, "recommends Contracting Parties to the Convention and invites Observer States to: 1. interpret the term "alien species" for the purpose of the implementation of the European Strategy on Invasive Alien Species as **not including native species naturally extending their range in response to climate change**" (*Cf.* Section 4.6.2 in this Code). As a results, also past mass migratory events in forest tree populations, postglacial recolonization routes and similar events are not considered in the definition of alien tree species. We focus on alien trees deliberately or accidentally introduced by man outside its natural past or present distribution, where "past" refers to the definition of "neophytes" (i.e. introduced after the 1,500) as used in the CBD context and defined by Pyšek et al. (2004).

[2] For the purposes of the present Code of Conduct the term "planted forest" is used in accordance with the FAO definitions (FAO 2012, 2015a, 2015b).

[3] In accordance with the CBD definition, "invasive alien species" means an alien species whose introduction and/or spread threaten biological diversity (Decision V/8 of the Conference of the Parties to the Convention on Biological Diversity). According to art. 3 of the Regulation EU no. 1143/2014, "invasive alien species" means an alien species whose introduction or spread has been found to threaten or adversely impact upon biodiversity and related ecosystem services. According to FAO (2012), **woody invasive species** are species that are non-native to a particular ecosystem and whose introduction and spread cause, or are likely to cause, socio-cultural, economic or environmental harm or harm to human health.

They are the following:

1.1 Be aware of regulations concerning invasive alien trees;

1.2 Be aware of which alien tree species are invasive or that have a high risk of becoming invasive, and of the invasion debt;

1.3 Develop systems for information sharing and training programmes;

2.1 Promote – where possible – the use of native trees;

2.2 Adopt good nursery practices;

2.3 Modify plantation practices to reduce problems with invasive alien tree species;

2.4 Revise general land management practices in landscapes with planted forests;

2.5 Adopt good practices for harvesting and transport of timber;

2.6 Adopt good practices for habitat restoration;

3.1 Promote and implement early detection & rapid response programmes;

3.2 Establish or join a network of sentinel sites;

4.1 Engage with the public on the risks posed by invasive alien trees, their impacts and on options for management;

5.1 Consider developing research activities on invasive alien trees species and becoming involved in collaborative research projects at national and regional levels;

5.2 Take global change trends into consideration.

2. CODE OF CONDUCT

2.1 Focus of the Code of Conduct: Planted Forests of (Invasive) Alien Trees

Planted forests are forests predominantly composed of trees established through planting and/or deliberate seeding (FAO 2012)[4]. Planted forest of introduced species (PFIS) is a subcategory of planted forest, where the planted/seeded trees are predominantly of introduced species (FAO 2012). The FAO 2015 Global Forest Resources Assessment (FRA), defines an **introduced species** as a species, subspecies or lower taxon, occurring outside its natural range (past or present) and dispersal potential, i.e. outside the range it occupies naturally or could occupy without direct or indirect introduction or care by humans, FAO (2012).

In FRA 2015 the term introduced is considered equivalent to non-native. In this Code the terms introduced, non-native, and exotic are considered equivalent to alien. In addition, in FAO FRA 2015, "**naturalised tree"** species are introduced tree species that spread and multiply by natural regeneration and are well established and acclimatised for several years. They do not need human help to reproduce/maintain populations over time (FAO 2012).

[4] In the context of the 2015 FAO Global Forest Resources Assessment (FRA), predominantly means that the planted/seeded trees are expected to constitute more than 50 percent of the growing stock at maturity. In addition, planted forest: (a) includes coppice from trees that were originally planted or seeded, (b) includes rubberwood, cork oak and Christmas tree plantations, (c) excludes self-sown trees of introduced species.

In this Code, the term **naturalised[5] alien tree** species will be used for better clarity, i.e. without omitting "alien". Not all alien trees will become naturalised. Similarly, naturalised **invasive alien trees** (i.e. invasive alien trees) are a subset of the naturalised alien trees, as many naturalised alien trees do not go on to become invasive, i.e. they do not threaten biological diversity and do not cause economic or environmental harm.

Therefore, the terms *alien tree*, *naturalised alien tree* and *invasive alien tree* are used throughout this Code of Conduct. The terms *planted forest* and *naturalised* are used in accordance with the FAO definitions (FAO 2012, 2015a, 2015b), the terms *alien* and *invasive* in accordance with the CBD definitions (COP 6 Decision VI/23), the Recommendations of the Standing Committee (Convention on the Conservation of European Wildlife and Natural Habitats) and the Regulation (EU) No. 1143/2014.

In 2010 the total area of planted forests was estimated to be 264 million ha (about 7 % of the total global forest area; FAO 2010a), and this increased to an estimated 277.9 million ha in 2015 (FAO 2015a, 2015b; Payn et al. 2015)[6]. Although there are marked differences between and within regions, it has been estimated that between 18% and 19% of planted forests comprise alien tree species (Payn et al. 2015; FAO 2015a, 2015b).

2.2 Audience and aims of the Code of Conduct

This Code of Conduct is addressed to all relevant stakeholders and decision makers in the 47 Member States of the Council of Europe. It aims to enlist the co-operation of the Forest sector (trade and industry, national forest Authorities, certification bodies and environmental organizations) and associated professionals in preventing, reducing and controlling possible risks and negative impacts. In particular, it is intended to provide guidance for the sustainable use of alien tree species in planted forests, to reduce the risk of the introduction of new invasive alien tree species and the negative impacts that might originate from the unregulated use of invasive alien trees. Containment of (invasive) alien trees to areas set aside for their cultivation must become an integral part of management of planted forests.

It complements the Code of Conduct on Horticulture and Invasive Alien Plants published by the Council of Europe (Heywood & Brunel 2009, 2011) aimed at the horticultural industry and trade and the European Code of Conduct for Botanic Gardens on Invasive Alien Species (Heywood & Sharrock 2013).

These three Codes should be taken into consideration by private or public gardens or arboreta in Europe with major collections of alien trees that are not considered planted forests of alien trees in the narrow sense. Although most of these gardens do not belong to any association or consortium they are important in terms of the plant collections they house and therefore can pose the same risks as botanic gardens or commercial nurseries in terms of invasive alien tree species.

Although prepared specifically for planted forests of alien trees in 47 Member States of the Council of Europe, many examples and many if not most of the recommendations for action contained in the Code will be of relevance to planted forests in other countries and regions, as a small number of alien tree species now form the foundation of planted forests in many parts of the world (Richardson 2011). National forest authorities or individual forest enterprises may wish to adapt the Code to meet their particular circumstances and requirements.

[5] According to Regulation EU no. 1143/2014 (Art. 3), an invasive alien species is in the naturalisation stage when its population is self-sustaining.

[6] Planted forest area has increased by over 110 million ha since 1990 and accounts for 7 percent of the world's forest area. The average annual rate of increase between 1990 and 2000 was 3.6 million ha. The rate peaked at 5.2 million ha per year for the period 2000 to 2010 and slowed to 3.1 million ha (2010–2015) per year, as planting decreased in East Asia, Europe, North America, South and Southeast Asia (FAO 2015 b).

2.3 A voluntary tool

This Code of Conduct is voluntary. All stakeholders concerned with the planning, the management and development of planted forests of alien trees, and the conservation of forestry resources, are actively encouraged to use and to implement it.

This Code does not replace any statutory requirements under international or national legislation but should be seen as complementary to them. Although voluntary, it is important that as many stakeholders as possible should adopt the good practices outlined in this Code so as to reduce the likelihood of compulsory legislation having to be introduced should self-regulation fail. Private forest enterprises and public forest managers may wish to publicise their adherence to the Code through adopting a symbol or logo indicating this. At the same time some of the principles of this Code could become part of forest certification schemes and sustainable forest management criteria and indicators.

2.4 Implementing, monitoring and evaluating the Code of Conduct

To be fully effective and to increase the likelihood of a long-term behaviour change, a voluntary Code should be widely disseminated and translated into national languages. This clearly stresses the importance of information campaigns aimed at preventing lack of knowledge, possibly coordinated by the key stakeholder's associations and with the support of the national authorities. A straightforward example is provided for by the implementation of the Code of conduct on invasive alien plants in Belgium during the AlterIAS LIFE+ project (Halford et al. 2014). National authorities should acknowledge that the issue of invasive alien trees is a major threat for species, habitats and ecosystems, and undertake measures to ensure that all the available legislation established to prevent introductions of invasive species from Forestry is fully understood, and effectively transposed, implemented and enforced.

National authorities should develop strategies and protocols for dealing objectively with conflicts of interest between those who benefit from the introduction, dissemination and cultivation of invasive alien trees, and those who perceive, and are affected by, negative impacts of these invasive alien trees.

3. THE PRINCIPLES OF THE CODE OF CONDUCT

The fourteen principles of this Code of Conduct are clustered in five groups: (1) Awareness; (2) Prevention & Containment; (3) Early Detection & Rapid Response; (4) Outreach and (5) Forward Planning.

3.1 Awareness

3.1.1 Be aware of regulations concerning invasive alien trees

Those engaged in the planted forest sector need to be aware of their obligations under regulations and legislation. The main obligations under existing laws and treaties are detailed in the Section 4 of this Code.

The Regulation (EU) No. 1143/2014, the Plant Health Directive 2000/29/EC, the Wildlife Trade Regulations (338/97/EC and 1808/2001/EC) and the Habitats Directive (92/43/EEC) only apply to the member countries of the European Union. Many other international conventions addressing issues of invasive alien species have been ratified by European and Mediterranean Countries (Shine 2007). These recommendations may be implemented in the European Union or in national legislation (of countries that ratified these treaties) and lead to the regulation of import and exports of plants and plant products, inspections, phytosanitary measures, possession, trade and release in the wild of invasive alien plants and quarantine pests. These regulations may therefore impact on the everyday work in the planted forest sector.

At the national (or subnational) level, some countries have legislation and/or regulations aimed at preventing possession, transport, trade or release in the wild of specific invasive alien trees[7].

3.1.2 Be aware of which alien tree species are invasive or that have a high risk of becoming invasive, and of the invasion debt

Over 430 alien tree species worldwide are known to be invasive alien trees, and the list is growing as more tree species are moved around the world and become naturalised in novel environments[8]. Increasing awareness of problems associated with invasive alien trees means that information on invasive alien tree species and ways of dealing with them is becoming more easily accessible - on the Internet, in scientific and popular publications, and via special interest groups. "Invasive elsewhere" is one of the most robust predictors of invasiveness. There is strong evidence that invasive alien tree species may replicate invasive behaviour in environmentally-similar conditions in different parts of the world.

Invasive alien tree species can have negative impacts even when they are not fully established or widespread (i.e., before they become naturalised *sensu* FAO FRA 2015)[9].

The fact that some alien forestry trees have not yet spread from given planted forests should not be taken as evidence that invasions will not occur in the future. Experience with the same species in planted forests in other parts of the world, including areas where the species have long residence times, should be evaluated to assess the extent of "invasion debt" (Richardson et al. 2015)[10].

[7] For example, in Norway, the 2005 white paper on the Government's environmental policy and the state of the environment in Norway (Report No. 21 - 2004–2005 - to the Storting), the new Forestry Act (Act of 27 May 2005, no. 31, relating to forestry) , the Nature Diversity Act (Act of 16 June 2009, no. 100), the Regulation on non-native trees (Regulation of 15 March 2013, no. 284), the national Strategy on Invasive Alien Species (published in May 2007) and the Norwegian Black List (Gederaas et al. 2012), are the main national specific documents referring to non-native trees. The Guidelines on trees, shrubs and plants for planting and landscaping in the Maltese Islands limit the use of alien trees in afforestation projects on agricultural land (MEPA 2002). The Iceland Forest Service has put forth a set of guidelines to afforestation planners: planting of alien trees within natural woodlands is discouraged (Gunnarsson et al. 2005). Planting in treeless land must be carefully assessed considering the phenomenal and unique importance of the Icelandic breeding waterfowl populations which are at risk from the forestry (*Cf.* Bern Convention, Recommendation No. 96 (2002) on conservation of natural habitats and wildlife, especially birds, in afforestation of lowland in Iceland (https://wcd.coe.int/). The Swedish Forestry Act placed restrictions on the planting programme of *P. contorta* in 1987, 1989 and 1991 due to extensive infection by *Gremmeniella abietina* in high elevation areas in northern Sweden after periods of extreme weather conditions from 1984 to 1987 (Karlman 2001). Many countries have national or sub-national "black lists" or other types of lists, identifying those alien tree species whose introduction is prohibited or discouraged due to their potential adverse effects on the environment or human, animal or plant health. An alternative approach used in other countries relies on the "white list" (or red, green and amber lists, see Perrings et al. 2005; Simberloff 2006) of low invasion risk alien species, including trees.

[8] Global lists of invasive alien trees are available in the scientific literature (e.g., Moore 2005; Richardson 2011; Richardson & Rejmánek 2011; Rejmánek & Richardson 2013; van Wilgen & Richardson 2014).

[9] Invasive alien tree species can have negative impacts as soon as they are introduced (Ricciardi & Cohen 2007; Jeschke et al. 2013; Jeschke et al. 2014); for example, allergic pollen can affect human health, they can act as vectors of new pests or pathogens for other forest tree species (e.g., Engelmark et al. 2001), they can modify ground vegetation, soil properties and soil fauna (Finch & Szumelda 2007), water balance, fire resilience at the stand level, within areas of their cultivation, relatively fast soon after being planted in the new environment (Woziwoda et al. 2014).

[10] According to Richardson et al. (2015) invasion debt is composed by four main components: (1) the number of species not yet introduced but likely to be introduced in the future given current levels of introduction/propagule pressure; (2) the establishment of introduced species; (3) the potential increase in area invaded by established species (including invasive species); (4) and the potential increase in impacts. These Authors suggest that invasion debt is a valuable metric for reporting on the threats attributable to biological invasions, that invasion debt must be factored into strategic plans for managing global change, and, as with other studies, they highlight the value of proactive management. However, given the uncertainty associated with biological invasions, further work is required to quantify the different components of invasion debt.

Alien tree species included in "black-lists" should not be used for new planted forests. However, black-lists should only be considered as guides and one should not assume that alien tree species not listed on them are safe. Additionally, in a huge country the translocation of a tree species from one part to another is just as likely to lead to invasions as are trans-continental introductions. For this reason, for Russia, Notov et al. (2011) propose the adoption of three-level system of sub-national lists called "black books".

Nevertheless, lists offer a positive approach for both companies and government agencies and could be used to fast-track approval of or reduce liability for forest owners when using low-risk non-native trees for plantations.

For each new alien tree species or provenance[11] introduced which has not already been evaluated, those[12] introducing the new alien tree species or planning new planted forests with the new alien tree species should run a risk assessment or risk analysis[13]. According to Křivánek & Pyšek (2006)[14] two main

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[11] "Provenance" in forestry science refers to the particular place where trees are growing or the place of origin of seeds or trees. For example, Norway spruce from different European countries, especially from Germany and Austria, has been used in afforestation in Norway for several decades. Such foreign provenances may differ in adapted ecological traits, such as phenology, frost hardiness, production and spread of seeds, resulting in different growth- and spread potential of the provenances (Aarrestad et al. 2014). In fact, most plant species exhibit spatial structuring of genetic variation throughout their range (Hamrick 1990). While translocation of individual plant species is sometimes proposed as a strategy to increase genetic variation within populations, individuals transferred across different environments may be poorly adapted to the new conditions. Furthermore, there is a risk of outbreeding depression or genetic swamping when divergent populations interbreed. These consequences of seed transfer must therefore be weighed against the potential benefits of increased genetic variation within founding populations (O'Brien et al. 2007; Aitken & Bemmels 2016). *Cf.* also the Council Directive 1999/105/EC of 22 December 1999 on the marketing of forest reproductive material (Article 2 (g): "for a species or sub-species, the region of provenance is the area or group of areas subject to sufficiently uniform ecological conditions in which stands or seed sources showing similar phenotypic or genetic characters are found, taking into account altitudinal boundaries where appropriate.").

[12] Various authors suggest that importers, developers and growers who are responsible for introducing potentially invasive alien species such as *Eucalyptus* spp., should be responsible for damages to the environment (i.e., 'polluter pays' principle), rather than allowing that burden to be borne by tax payers or neighbouring private landowners who are affected (Richardson 1998a; Buddenhagen et al. 2009; Chimera et al. 2010; Witt 2010; McCormick & Howard 2013; Lorentz & Minogue 2015).

[13] Examples of risk analysis for alien tree species are available in the web page of the LIFE project IAP-RISK "Mitigating the threat of invasive alien plants in the EU through pest risk analysis to support the EU Regulation 1143/2014" (http://www.iap-risk.eu/). Risk assessments for *Robinia pseudoacacia* and *Ailanthus altissima* were prepared, respectively in 2012 and 2013, by E. Boer for the Invasive Alien Species Team of the Netherlands Food and Consumer Product Safety Authority (https://www.nvwa.nl/documenten-nvwa). According these two RAs, "in the neighbouring countries of the Netherlands *Robinia pseudoacacia* is an invasive plant, particularly by its effects on the natural environment. It can invade valuable nature conservation areas, especially calcareous and dry grasslands. Infestations cause a shift in species composition, favouring more ruderal and less valuable plant species. The effects on the nitrogen balance of the soil are irreversible and long-lasting. For the Netherlands, identifying and monitoring those sites which are particular susceptible to Black locust infestations is important to take effective measures if needed. Amongst the endangered areas in the Netherlands are the forests on steep slopes ("hellingbossen") in the southern part of Limburg, where *Robinia pseudoacacia* has been planted for erosion control and the calcareous grasslands, which are also located in southern Limburg. However, undesirable spread and impact may also occur in other areas throughout the country. On the contrary, In the Netherlands, *Ailanthus altissima* is mainly found in urban areas. Areas outside cities where the tree has been found (along the river Waal, in the central reserve of motorways) should be subject to an eradication programme to prevent establishment in natural areas. The impact of *Ailanthus altissima* as invasive species in the Netherlands is limited so far; this implies that new infestations can still be controlled. From neighbouring countries, however, it is clear that by its invasive traits (high seed production and easy". Risk assessments are available also for *Eucalyptus glaucescens* (low risk), *E. gunnii* (low risk), *E. nitens* (low risk) (http://www.nonnativespecies.org/index.cfm?sectionid=51).

groups of risk assessment models can be considered, based on the methods used and the phase of the invasion process they target: (1) pre-introduction models predicting the potential behaviour of an alien tree species prior to its introduction; (2) post-introduction models predicting the future behaviour of an alien tree species that have already become naturalised or invasive in the new area. There are over 100 risk assessment and risk analysis schemes for plant species (Leung et al. 2012; Křivánek & Pyšek (2006), with some decision schemes developed specifically for trees or woody plants (Reichard and Hamilton 1997; Pheloung et al. 1999; Haysom & Murphy 2003; Widrlechner et al. 2004; Kumschick & Richardson 2013; Wilson et al. 2014). However, only a few risk assessment methods are in line with the requirements of the Regulation (EU) No. 1143/2014 (Roy et al. 2014)[15].

3.1.3 Develop systems for information sharing and training programmes

The efficacy of any strategy to address invasive alien trees, including the capacity to produce reliable risk assessment reports (see principle 3.1.2), depends on the available information, and on the sharing of data, knowledge and experience[16]. Information sharing systems would greatly improve the ability of authorities to prevent the introduction and spread of invasive tree species (Katsanevakis et al. 2014). Also, invasive alien tree species management requires specialist knowledge and skills which can only be developed over time. The capacity and awareness of land owners, forestry officials and other stakeholders are crucial for the effective implementation of the principles of this Code. There is a need to strengthen training institutions and to revisit the training curricula of forestry personnel and other stakeholders in silviculture, species and provenance identification, reduced impact logging, resource assessment, prioritisation, risk assessment and risk analysis, and in the management of both natural forests and planted forests of (invasive) alien trees.

3.2 Prevention & Containment

Actions aiming at preventing the potential risk posed by invasive alien trees or limiting their spread from planted forests, might often be very useful also to contrast or limit the spread of other pest and alien species in general. It is necessary to take actions aiming to prevent potential risks posed by invasive alien trees; below are some of the key approaches to the matter.

3.2.1 Promote – where possible – the use of native trees

The use of native species or non-invasive alien or less-invasive[17] alien tree species as alternatives for highly invasive alien species in planted forests should be always considered[18], as should the precise provenance[19] of seeds and germplasm[20].

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[14] To assess the validity of previously developed risk assessment schemes in the conditions of Central Europe, Křivánek & Pyšek (2006) tested the (1) Australian weed risk assessment scheme (A-WRA; Pheloung et al. 1999); (2) the A-WRA with additional analysis by Daehler et al. (2004); and (3) the decision tree scheme of Reichard & Hamilton (1997) developed in North America, on a data set of 180 alien woody species commonly planted in the Czech Republic. The study revealed that the A-WRA model, especially with additional analysis, appears to be a promising template for building a widely applicable system for screening out invasive plant introductions in the central European region. Gordon et al. (2011, 2012) used the A-WRA to evaluate 38 commercially important *Eucalyptus* species.

[15] The article 5 of the Regulation (EU) No. 1143/2014 list the criteria required to perform a risk assessment for the purposes of article 4, i.e. for the procedure to follow to identify the invasive alien species of Union Concern. Other risk assessment schemes, with additional or different criteria, shall be carried out in relation to the current and potential range of the invasive alien species to be assessed, for other specific purposes.

[16] See also COP 6 Decision VI/23 "Alien species that threaten ecosystems, habitats or species", Guiding principle 8: Exchange of information.

[17] In France and Belgium (Biogeco, INRA, Univ. Bordeaux, Gembloux Agro-Bio Tech, Université de Liège, Gembloux and BFP, INRA, Univ. Bordeaux, Villenave d'Ornon) a multidisciplinary study on *Robinia pseudoacacia* genetic and phenotypic diversity is evaluating the difference in invasive behaviour of existing populations of this species (http://www.neobiota2016.org/wp/wp-content/uploads/neobiota_2016_book-of-abstracts_web.pdf).

For example, Lorentz & Minogue (2015) remark that trait selection during breeding is potentially a very effective containment approach for managing alien *Eucalyptus* invasion risk. The likelihood of spread can be reduced by decreasing fecundity or by increasing the age to maturity, although the later 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 thought to be a feasible goal for *Eucalyptus* (Gordon et al. 2012), and elimination of fertile pollen production has already been accomplished in the transgenic hybrid *E. grandis* × *E. urophylla* (AGEH427) (Hinchee et al. 2011). Ensuring containment of genetically modified trees through sterility could be significant because it eliminates the need for costly, uncertain and complex ecological research to understand and predict the impacts (FAO 2010d).

However, the major limitation to this approach is that the permanence of containment technology is still uncertain (FAO 2010d; Lorentz & Minogue 2015). An additional obstacle to this solution is that FSC regulations currently expressly forbid any use of GM trees (Strauss et al. 2004; Brunner et al. 2007; Meirmans et al. 2010: Richardson 2011). In addition, some invasive alien tree species (*Ailanthus altissima*, *Populus* spp., *Robinia pseudoacacia*) also spread by vegetative propagation.

Planted forests of alien species of *Acacia*, *Eucalyptus* and *Pinus* have typically been relatively free of pest problems during the early years of establishment due to a separation from their natural enemies. This situation has however changed dramatically recently, as pests are accidentally introduced, but also as native organisms have started to infect and infest alien trees (Payn et al. 2015; Wingfield et al. 2015).

BOX 4.2.1.1 - Use of native tree species to improve carbon sequestration and contribute to solving environmental problems in the timberlands in Biscay, northern Spain.

The rapid transformation of natural forest areas into fast-growing non-native planted forests, where the main objective is timber and pulp production, has led to a neglect of other services planted forests provide in many parts of the world. One example of such a problem is the county of Biscay in northern Spain where the management of these planted forests has negative impacts on the environment, making it necessary to evaluate alternative tree species for use in forestry. The actual crisis in the forest sector of the region could be an opportunity to change to planted forests of native tree species that could help restore ecosystem structure and function. However, forest managers in the region are using the current interest on carbon sequestration by forest to persist with the "pine and eucalyptus culture", arguing that these species provide a substantial C sequestration service. Moreover, they are promoting the expansion of eucalypt

[18] FAO Principle 9 "Conservation of biological diversity" states that "…FAO encourages the establishment of planted forests with indigenous species over exotic species, as they produce a wider range of products and benefits, among them a lower environmental risk and an increase in biodiversity. Introduced species should be selected only in relation to specific management objectives, market conditions and ecological site conditions. The decision to plant introduced species should carefully evaluate the risk that these species may become invasive and have adverse effects on the local biodiversity…" (FAO 2010c). In addition, FAO Principle 10 "Conservation of biological diversity" states that "… Guidelines include but are not limited to: … selecting indigenous species for the establishment of planted forests if they are equal to or better than introduced species for the purpose intended…" (FAO 2006b). See also the "Protocol for species introductions" proposed by Haysom and Murphy (2003). Cf. also Richardson (1998); FAO (2010c); Gordon et al. (2012); Lorenz & Minogue (2015); Peltzer et al. (2015).

[19] *Cf.* Principle 3.2.1 (footnote n. 10).

[20] *Cf.* the Pan-European guidelines for afforestation and reforestation with a special focus on provisions of the UNFCCC. Adopted by the MCPFE Expert Level Meeting on 12-13 November 2008 and by the PEBLDS Bureau on behalf of the PEBLDS Council on 4 November, 2008. In particular, at Ecological Guidelines, p. 21 "species, provenances, varieties or ecotypes outside their natural range should only be used where their introduction would not endanger important and/or valuable indigenous ecosystems, flora and fauna. Those that are likely to be invasive should be avoided using the CBD Guiding Principles for the Prevention, Introduction, and Mitigation of Impacts of Alien Species that threaten Ecosystems, Habitats or Species". *Cf.* also Aarrestad et al. (2014).

plantations to obtain biomass for the pulp and paper industry and for bioenergy (Rodríguez-Loinaz et al. 2013) Whether this argument used by the foresters is well-founded or whether the use of native species in plantations could improve the C sequestration service in Biscay, while avoiding the environmental problems that the plantations cause, is controversial.

Rodríguez-Loinaz et al. (2013) showed that substituting existing planted forests of alien trees with planted forests of native tree species has good potential for increasing C sequestration. Although short- and mid-term outcomes may differ, when the long-term (more than 50 years) is considered, the C stock in the planted forests of native species is the greatest. Thus, changing from pine and eucalypts to planted forests of native tree species sequesters more C in the long-term, while solving some of the environmental problems caused by (invasive) alien trees. As C sequestration initiatives only make sense if there is a good chance of long-term persistence of the C stocks that are created, there is no C sequestration argument for the foresters to continue with the policy of using of fast-growing invasive alien trees (Rodríguez-Loinaz et al. 2013).

BOX 4.2.1.2 - An evaluation of the experiences of farmers planting native trees in rural Panama: implications for reforestation with native species in agricultural landscapes.

In the Republic of Panama, reforestation is becoming a popular strategy to protect the country's remaining forests and to restore degraded lands (Garen et al. 2009). The Panamanian government has taken several steps to encourage landholders to plant trees on their land, either in the form of planted forests or as agroforestry or silvopastoral systems by requiring that landholders replace trees that are cut and removed in logging operations, and by providing financial incentives and tax breaks for those engaged in reforestation activities. Since the adoption of the country's Tropical Forestry Action Plan in 1990, government officials also launched a series of agroforestry projects to address rural development and environmental degradation, most notably within the Panama Canal Watershed (Garen et al. 2009). The majority of Panama's agroforestry projects and planted forests, however, are dominated by fast-growing, alien timber species such as teak (*Tectona grandis*) and Caribbean pine (*Pinus caribaea*) (Fischer & Vasseur 2000; Wishnie et al. 2007). While monocultures of alien trees can produce high quality timber, they have also been found to support low-levels of plant biodiversity and may promote soil erosion (Lamb et al. 2005; Wishnie et al. 2007). Alien tree species also provide limited goods and services to local landholders (Lamb et al. 2005; Wishnie et al. 2007), but initial studies in two rural communities indicate that Panamanian farmers use native tree species regularly for a variety of purposes (Aguilar & Condit 2001; Love & Spaner 2005). Moreover, the long-term sustainability of agroforestry projects dominated by alien trees might be compromised, since alien tree species may be more expensive to maintain than native trees (Fischer and Vasseur 2000, but also see Craven et al. 2008). In light of these and other trends, interest in reforestation with native species in Panama has increased in recent years, as native species have been found to have more positive impacts on the environment than alien trees and can provide a host of services to local people (Wishnie et al. 2007). Yet native trees often are not used in reforestation projects due to a lack of both social and biophysical data about native tree species (Aguilar & Condit 2001; Wishnie et al. 2007; Garen et al. 2009).

3.2.2 Adopt good nursery practices

Best practice methods relating to species and provenances of seed (Karlman 2001), seedling production, weed, pest and disease control should be adopted (FAO 2011). Weeds should be identified, recorded, and eradicated where possible, before planting. The EPPO standard PP 1/141 (3) describes the conduct of trials for the efficacy evaluation of herbicides in tree and shrub nurseries including nurseries within forest stands (EPPO 2009)[21].

Nurseries can act as important sources of alien species into planted forest sites. Many forest pests, both insects and pathogens, have also entered new lands via nursery stock22.

BOX 3.2.2.1 Sudden oak death (Phytophthora ramorum).

Phytophthora ramorum emerged in the US as a forest pathogen causing mortality in oak (*Quercus* spp.) and tanoak (*Notholithocarpus densiflorus*) in California in the mid-1990s, and appeared about the same time in Europe as a nursery pathogen. The pathogen produces spores on a wide variety of foliar hosts, including many popular landscape species. Population genetics studies indicate separate origins for the North American and European populations, and that the North American forest infestation likely originated in nurseries (Ivors et al. 2006; Mascheretti et al. 2008). Although nursery stock has been the major pathway for long-distance spread, the pathogen spreads locally in rain, as well as via surface water runoff from infested nurseries. The pathogen has spread to forests in 14 counties in coastal California and one county in southwest Oregon. In Europe, the pathogen has spread to woodlands in Ireland, the UK, Norway, the Netherlands, and Germany, and has been found in nurseries in sixteen other European countries and Canada (Liebhold et al. 2012). According to Ivors et al. (2006) higher genotypic diversity of *Phytophthora ramorum* in nurseries could be explained by the repeated exchange of pathogen genotypes through the trade of infected plant material, by strong selection pressure selecting new genotypes created through mitotic recombination or mutation, or from both mechanisms. Cultural practices and chemical treatments may be partially responsible for such selection pressure in nurseries. The potential role of plant trade in the creation of an "artificial" panmictic population at the continental level is highlighted by (ii) the observation that rare genotypes were found more than once within Europe, particularly in the UK, where the EU4 genotype was found multiple times in different regions, and (ii) the detection of an EU genotype within Oregon and Washington nurseries (Ivors et al. 2006).

3.2.3 Modify plantation practices to reduce problems with invasive alien tree species

Containment of alien trees to areas set aside for their cultivation must become an integral part of silviculture and must be incorporated in best-management practice guidelines as well as certification schemes for planted forests (e.g., Engelmark et al. 2001; Richardson & Rejmánek 2004; Richardson 2011; Dodet & Collet 2012; Felton et al. 2013). Wingfield et al. (2015) have called for the global strategy to promote the health and sustainability of planted forests. Practices to reduce problems with invasive alien forestry trees should be incorporated in such a strategy.

Examples of practices that, case by case, should be applied in planted forests of (invasive) alien trees include the following:

- Research findings[23] on (invasive) alien trees should be applied to identify the most appropriate sites for their cultivation within landscapes;
- Biodiversity issues must be considered in planted forest design (COP 11 Decision XI/19 8 - 19 October 2012 - Hyderabad, India[24]);

[21] *Cf.* also, EPPO (2012). EPPO Technical Document No. 1061, EPPO Study on the Risk of Imports of Plants for Planting EPPO Paris. www.eppo.int/QUARANTINE/EPPO_Study_on_Plants_for_planting.pdf, and Orwig (2002).
[22] See also the FPS COST Action FP1401 "A global network of nurseries as early warning system against alien tree pests (Global Warning)", [http://www.cost.eu/COST_Actions/fps/Actions/FP1401].
[23] See also Principle 3.5.1.

- Avoid converting natural habitats for cultivation[25];
- Restrict planted forest to areas where alien tree species are already present[26];
- Limit the total allowable area of planted forests, aggregate planting sites, and reduce the total boundary length;
- Save or plant 2-3 rows of native and/or less invasive alien tree species around external boundaries of the planted forest with alien trees or along margins of unplanted reserve areas inside planted forests[27];
- Design planted forest shape to minimise edges at right angles to prevailing winds during seed release season;
- Whenever possible, include sites with boundaries from where spread is difficult or acceptable (e.g., grazed areas, actively managed planted forests, wide roads);
- Whenever possible, use mixed-species planted forests and encourage structural diversity through different age classes[28];
- Encourage the establishment of representative natural forest within the planted forest and, where possible, restore natural forests on appropriate sites (Secretariat of the Convention on Biological Diversity 2009);

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[24] COP 11 Decision XI/19 on "Biodiversity and climate change related issues: advice on the application of relevant safeguards for biodiversity with regard to policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries": "When designing, implementing and monitoring afforestation, reforestation and forest restoration activities for climate change mitigation, consider conservation of biodiversity and ecosystem services through, for example: ".. Prioritizing, whenever feasible, local and acclimated native tree species when selecting species for planting; (iii) Avoiding invasive alien species". See also: Integrate+, a demonstration project funded by the German Federal Ministry of Food and Agriculture (BMEL) to establish a European network of demonstration sites for the integration of biodiversity conservation into forest management (http://www.integrateplus.org/); Kraus and Krumm (eds.) (2013). Importantly, since the Second Ministerial Conference on the Protection of Forests in Europe on 16-17 June 1993, Helsinki/Finland (Resolution H1 - General Guidelines for the Sustainable Management of Forests in Europe) "sustainable management" means the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems". *Cf.* also Carnus et al. (2006).

[25] FAO Principle 9 "Conservation of biological diversity": " … FAO disapproves of the substitution of indigenous forest, in particular primary forest, ecologically significant ecosystems (e.g. wetlands, peatlands) or fertile agricultural land with planted forests as this would cause unwanted damage to valuable ecosystems or threaten livelihoods …" (FAO 2010c). **Natural habitats** should include forests that were never cleared (so called primary forests, *sensu* Peterken 1974, 1981) or from forests that already existed before a certain threshold date (so-called ancient forests, sensu Hermy et al.1999; Hermy & Verheyen 2007). See also Principle 10 (Conservation of biological diversity) and guidelines included in this principle, according to FAO (2006b).

[26] The scale at which this measure should apply have to be assessed case by case.

[27] Engelmark et al. (2001) hypothesize that the most fringe spread come from seed produced by edge trees, which have more green foliage then internal trees and are closer to spread-prone areas.

[28] As remarked by Verheyen et al. (2016), with global change, monospecific planted forests are increasingly vulnerable to abiotic and biotic disturbances. As an adaption measure the Authors suggest moving to plantations that are more diverse in genotypes, species, and structure, with a design underpinned by science. TreeDivNet, a global network of tree diversity experiments, responds to this need by assessing the advantages and disadvantages of mixed species plantations. The network currently consists of 18 experiments, distributed over 36 sites and five ecoregions. *Cf.* Evans (2009b); Brockerhoff et al. (2008).

- Prevent plantings at sites most favourable for long-distance dispersal of seed or pollen (hill tops, ridges);
- Prevent plantings and minimise disturbance near wetlands, rivers and streams and create buffer zones[29];
- Prevent plantings near “Natura 2000” sites and other protected areas or endangered habitats;
- Minimise soil movement, transport and disturbance in or around planted areas;
- Stabilise disturbed soils as soon as possible.

While some of these rules can be considered of general utility, other good practices refer to specific alien tree species and aim to mitigate specific impacts, as in the case of the practices suggested by Finch & Szumelda (2007) for Douglas fir in temperate forests of Central and Western Europe30, by Ledgard (2002) for the same species in New Zealand, by Engelmark et al. (2001) for lodgepole pine in Sweden, by Rejmánek and Richardson (2011), Calviño-Cancela and Rubido-Bará (2013), Lorentz and Minogue (2015) for Eucalyptus31.

Calviño-Cancela and Rubido-Bará (2013) suggest the establishment of a safety belt around eucalypt plantations in Spain to reduce eucalypt spread from plantations in the absence of fire. This measure would require the elimination of all newly recruited individuals in this safety belt (e.g. a 15-m wide belt could reduce the probability of eucalypt spread in more than 95 %) before they mature and start producing their own seeds, thus hindering the advance of the front line of invasion. For this purpose, Calviño-Cancela and Rubido-Bará (2013) recommend managing operations at about 1–2-year intervals, so that saplings can be easily uprooted, thus preventing resprouting. Their results refer to a situation without fire. Fire stimulates regeneration (Gill 1997) and could increase dispersal distances, so that additional measures would probably be needed to control E. globulus spread after fires. In addition, Catry et al. (2015) suggest planting sterile Eucalyptus trees and to prioritise control plans in regions with higher probability of recruitment.

An important responsibility of forestry authorities is to protect water quality in streams, rivers, and lakes from potential degradation from operations such as timber harvesting, site preparation, roads and skid trails, fertilisation, and herbicide applications (Neary 2011). Planted forest practices, including clear-felling and thinning, are recognised as a potential source of pollution to receiving waters and are a risk to the ecological status of surface waters32 (e.g., Drinan et al. 2013). Best management strategies should therefore be applied for reducing the run-off of planted forest-derived nutrients to receiving waters.

[29] Type and size of the buffer would depend on the alien tree species used in the planted forest. For example, *R. pseudoacacia* is able to invade land that has been abandoned while tree and shrub cover in the buffer may prevent its spread. Therefore, for this species, it would be advisable to have a buffer area with a high cover of native shrubs and/or trees or, in the case of grassland strips, not to change the intensity of disturbance (i.e. agricultural activities).

[30] “Limitation of the total area stocked with Douglas fir (42 % in certain regions seems to be too much); preserving Douglas fir free landscapes (not guaranteed today); avoiding pure stands (especially in private forests this is not at all guaranteed); planting in an open design to create less shaded below canopy environments; keeping away Douglas fir from areas with valuable biodiversity (e.g. ancient deciduous woodlands); preservation of old stands of Douglas fir for scientific purposes (not guaranteed today); installing an early warning system to identify possible problems (not installed until now)”. (from Finch & Szumelda 2007).

[31] To avoid natural spread, eucalypts should not be planted near rivers and streams. Temporarily flooded or eroded banks are suitable habitats for spontaneous establishment of their seedlings. Moreover, their seeds can be dispersed for long distances by running water (Lorentz & Minogue 2015).

[32] FAO Principle 8 “Maintenance of environmental sustainability and forest health”: “…Planting forest in areas that did not have trees before may cause potentially damaging side effects. They can reduce the local availability of water particularly in catchment areas that are fed by small rivers.…” (FAO 2010c).

The impact of invasive alien conifers on hydrology can be enormous, particularly where they replace non-forest vegetation. In South Africa, invasive alien pines were estimated to use 232 million m^3 of water per year, about 7 % of water use by all invasive alien plants and about 17 % as much as all commercial forestry (Le Maitre et al. 2000). Run-off in heavily invaded catchments is reduced by 30-70 % (Van Wyk 1987). In New Zealand, conifer plantations can dramatically lower mean water flows and lower minimum flows than either native forest or pasture, but the changes vary greatly depending on the precise nature of the conversion, stand management and harvesting regimes. However, the hydrological impacts of invasive, self-sown alien conifers have not been quantified in New Zealand (Simberloff et al. 2010).

The increase in the use of woody biomass as a feedstock for bioenergy production has raised questions about potential impacts on water quality. Best management practices for forest bioenergy programs have been developed and implemented since the early 1970s to ensure that forest harvesting can be conducted with minimum impact on water quality. Although these best management practices were originally designed to minimise water quality impacts, they can be used for a variety of environmental concerns (Loehr et al. 1979; Neary 2013).

Gene flow is a primary determinant of potential ecological impacts of planted forests of (alien) transgenic tree. Di Fazio et al. (2012) measured gene flow from hybrid poplar plantations and showed that most pollination and seed establishment occurred within 450 m of the source, with a very long tail[33]. Specific containment measures could be applied also at the plantation level[34], both in the case of confined field trials and unconfined releases (Häggman et al. 2013).

Good planted forest practices could also limit the spread of pathogens and pests within planted forests and from infested sites to native species and ecosystems (e.g., Engelmark et al. 2001; FAO 2011).

The use of good quality forest reproductive material derived from a suitable and traceable provenance and correctly identified is the key to the establishment of a planted forest. Finally, good planting practices and restrictions should be always supported by monitoring for wildings and targeted removal programs.

3.2.4 Revise general land management practices in landscapes with planted forests

Management practices which can enhance biodiversity in planted forests are essential if the goals of sustainable forest management are to be met. In many cases, options exist for managing planted forests of (invasive) alien trees and adjoining areas (invaded or potentially invasible) by manipulating disturbance regimes (e.g., fire cycles, grazing levels) to impede invasion.

The management of planted forests should promote biodiversity (e.g., Zapponi et al. 2014), both within the planted forest itself and in areas of natural forest that are retained within the planted forest landscape (e.g. establish planted forests on degraded sites and retain areas of high biodiversity value protected) as recommended by the Secretariat of the Convention on Biological Diversity (2009). Managers can modify the silviculture of planted forests in other ways to enhance diversity. For example, small variations in the timing and type of site preparation can affect the development and composition of the understory (Carnus et al. 2006).

[33] Gene flow covers great distances in *P. trichocarpa*, with effective pollination distances possibly averaging as much as 7.6 km (Slavov et al. 2009; Di Fazio et al. 2012).

[34] E.g., in the case of GM *Pinus radiata*, specific guidelines are provided by the Environmental Risk Management Authority New Zealand (2009), Field testing genetically modified organisms in containment Under section 40(1)(c) of the HSNO Act 1996.

Specific attention and management practices should be followed in the case of planted forests of genetically modified trees, such as hybrid or transgenic poplars and conifers (FAO 2006b, 2010c; Brunner et al. 2007; Strauss et al. 2009). In Canada and many other countries, regulatory guidelines have been created regarding the introduction of such plants with novel traits (which in Canadian regulation[35] includes aliens as well as transgenics; Bonfils 2006; Meirmans et al. 2010).

Planted forest owners should be aware of those forestry activities that favour the spread of invasive alien tree species. For example, coppicing was found to be a driver of the invasion by *R. pseudoacacia* and *A. altissima* in South Tyrol, Northern Italy. Radtke et al. (2013) concluded that the currently applied coppice management, which consists of repeated clear cuttings each 20–30 years, favours the spread of both invasive tree species. Thus, they suggest an adaptation of the management system to avoid further invasion.

Fire management in planted forests needs to be based on prediction, prevention and preparedness, supported by public awareness, monitoring, rapid response and community-based fire management. Fire weather prediction models have been developed in many countries, while developing countries are improving their capacity and capability for predicting, preparing and preventing destructive fires. The risk of promoting the spread of fire-tolerant or pyrophytic alien trees[36] must be always taken into account when planning the use of prescribed burning in planted forests. A valuable reference is Fire management: voluntary guidelines. Principles and strategic actions (FAO Fire Management Working Paper No. 17, 2006c)[37], which outlines voluntary guidelines for fire management, including in planted forests.

Finally, tailored management practices should be followed in the case of planted forests for bioenergy production (SRF/SRC), for a careful choice of new planting sites, for favouring biodiversity (Weih 2008; Framstad 2009), protecting hydrology (Christen & Dalgaard 2012), conserving landscape values and for the restoration of the site after the cultivation cycle (Hardcastle 2006; McKay 2011; Neary 2013; Caplat et al. 2014). Development of Forest Management Decision Support Systems for planted forests of alien trees is recommended.

3.2.5 Adopt good practices for harvesting and transport of timber

Native and alien trees are attacked by a wide range of pathogens, including bacteria, viruses, and many fungi and oomycetes. Insects and other invertebrates attack all parts of the plant, with defoliators and borers causing most direct damage; other pests may be more evident as disease vectors (FAO 2011; Boyd et al. 2013; Wingfield et al. 2015). Timber movement is a well-known pathway for many of these pests.

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[35] Canada has adopted a cautious approach with its federal science-based regulatory framework, put in place in 1993 to require that the products of biotechnology meet high standards for human health and environmental safety. The framework is based on the development of regulations under existing legislation and using the Canadian Environmental Protection Act as a "safety net" for products that would not be appropriately covered under other Acts. *Cf*, also the Cartagena Protocol on Biosafety (http://bch.cbd.int/protocol).

[36] For example, *A. dealbata'* resprouting ability and its pyrophytic seeds allow this species to easily establish after fire in the northwest of the Iberian Peninsula (Sanz Elorza et al. 2004; González-Muñoz et al. 2011). *Acacia saligna* and *A. cyclops* spread in Israel has been considerably promoted by wild fires (Danin 2000). Maringer et al. (2012) describe the colonization of burned patches by *Ailanthus altissima* and *Robinia pseudoacacia* on the southern slopes of the Alps. Todorović et al. (2010) suggest that the post-fire invasive potential of *Pauwlonia tomentosa* can, at least in part, be explained at the germination level.

[37] FAO Principle 7 "Fire effects on ecosystems" states that: "Fire should be managed in an environmentally responsible manner to ensure properly functioning and sustainable ecosystems into the future" and that aspects of the principle include but are not limited to: "minimizing and preventing the introduction and spread of pest or invasive plants and animals, plant diseases, insect pests and biological contaminants after fires or fire suppression activities; conducting planned burns in a manner that minimizes the spread of unwanted alien species and promotes or re-establishes natural or other preferred species" (FAO 2006c).

Harvesting[38] and transport of (invasive) alien trees should be planned, supervised and undertaken by appropriately trained personnel. Good practices should minimise the risk of further spread of invasive alien tree species, and the disturbance that could promote the establishment of other invaders. Careful planning will substantially reduce the road density[39] required within a planted forest, the number of temporary timber extraction tracks, and minimise adverse environmental impacts, such as soil disturbance, compaction and erosion. Whenever feasible, alien trees should be harvested individually or in small groups, to limit the risk of creating suitable habitats for other invaders.

Install appropriate water and sediment controls and prevent runoff flowing directly into waterways. Keep machinery out of water bodies and riparian margins. Clean and check machinery where the transfer of propagules of invasive alien tree species is an identified risk.

Forest personnel should be trained to recognise and report unusual pests and symptoms of diseased or infested trees, and to carry out practices that reduce the risk of pest and alien species or propagules moving to other locations[40]. Personnel should wear outer layers of clothing and footwear that are not “seed friendly” (*sensu* USDA 2012) to minimise the risk of spreading invasive alien species propagules accidentally.

3.2.6 Adopt good practices for habitat restoration

It is necessary to adopt specific guidelines for the restoration of sites previously occupied by planted forests of (invasive) alien trees. Restoration objectives can be 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 (invasive) alien trees. However, not all planted forests of alien tree develop species-rich understories; some remain as alien tree monocultures. Low light intensity below the canopy, distance to seed sources, inhospitability to seed dispersers, poor soil or litter conditions for seed germination or seedling growth, intensive root competition with the planted alien species, chemical inhibition and other forms of allelopathy and plant interactions, plantation design, or periodic disturbances by organisms or any external factor are likely causes that require careful consideration (Lugo 1997).

Specific guidelines for restoration of sites previously occupied by planted forests of *Robinia pseudoacacia* have been produced in the Piedmont region of Italy[41]. Sturgess & 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 planted forests of alien conifers on ancient woodland sites. Szitár et al. (2014) assessed the recovery of open and closed grasslands over five years following the removal of planted forests of alien pine species through burning at an inland sand dune system in Hungary. Arévalo and Fernández-Palacios (2005) proposed continuous elimination of *P. radiata* and enrichment with new individuals of *P. canariensis* on Tenerife,

[38] Harvesting is the end-point of a planted forest cycle and comprises logging, felling, trimming, extraction, sorting, stacking and log transportation. A poorly planned or executed operation can have unnecessary and extensive environmental impacts (FITEC 2007).

[39] During construction of new road corridors or widening of existing roads, the newly created forest edge is vulnerable to the invasion of nonnative vegetation. Disturbance from earthworks facilitates the weed invasion process through vegetation clearing and by the importation of seeds and plant parts carried on the vehicle (Goosem et al. 2010). The primary objective for a planted forest access network is the extraction, storage and transport of harvested forest product, but other objectives may include recreation activities (where relevant) and the facilitation of fire suppression activities. See also the “Guidelines for the Conservation and Sustainable Use of Biodiversity in Tropical Timber Production Forests” by IUCN, revised version June 2006, 62 pp.

[40] See also the FAO Guide to implementation of phytosanitary standards in forestry.

[41] http://www.regione.piemonte.it/foreste/images/files/pubblicazioni/esotiche.pdf For Italy see also Maltoni et al. (2012).

Canary Islands (Spain). Hughes (2003) and Moss & Monstadt (2008) propose management guidelines for the restoration of floodplain forests[42] in Europe.

3.3 Early Detection & Rapid Response

3.3.1 Promote and implement early detection & rapid response programmes

Early detection and initiation of management can make the difference between being able to employ feasible strategies and facing the necessity of retreating to a more expensive defensive strategy (mitigation, containment, etc.). Proactive measures to reduce the chances of invasions and to deal with problems at an early stage must be incorporated in standard silvicultural practices. Developing alarm lists of possible new alien tree invaders can also enable more rapid reaction (Richardson 2011; Faulkner et al. 2014).

The relatively long initial lag phase between introduction and naturalisation/invasion and slow dynamics observed in many alien tree species, in comparison with other plant species, offers opportunities to control the alien species while escaped populations are still small (Finnoff et al. 2007; Dodet & Collet 2012).

Any signs of alien tree naturalisation or invasiveness reported inside the planted forest or in its proximity should be carefully monitored so as to avoid serious problems developing. If the planted forest includes an area of native vegetation or it is close to a natural or protected area, any invasive alien tree species detected in it should be eradicated, controlled or contained.

Conifer wildings[43] of alien species lend themselves to control, as they are relatively easy to detect (most invasions are into grasslands and shrublands), and their direction of spread (downwind), and age when significant seed production begins (usually 10-15 years) is very predictable. There are therefore good opportunities to intercept the spread sequence early in the cycle, and prevent wildings becoming dominant and uncontrollable outside the planted forests (Froude 2011).

However, experience with alien conifers in new environments indicates that spread events could begin at any time, even if little significant spread had been observed up to that time. Possible reasons could be synchronisation of all factors needed for successful spread (e.g. plentiful seed, low herbivores/

[42] Very few floodplain forests remain in Europe. A large portion of their original area has disappeared and remaining fragments are often in critical condition Hughes (2003). In 1981 a report produced by the Council of Europe (Alluvial forests of Europe by Yon D, Tendron G) highlighted the very reduced extent of these floodplain forests remains. As well as reduced forest extent, there are concerns over the quality of remaining forests. In many locations, natural, self-regenerating forests have been considered unproductive and replaced with productive planted forests (often using hybrid poplars) within the floodplain forest zone. A direct consequence of these activities has been a steady loss throughout Europe of naturally regenerating stands of the endangered *Populus nigra* (Black Poplar), with near extinctions in countries like the United Kingdom, Belgium and the Netherlands (Hughes 2003; see also the European Forest Genetic Resources Programme EUFORGEN - http://www.euforgen.org/publications/publication/black-poplar-empopulus-nigraem/; Gumiero et al. 2013).

[43] "Wildings" is the term used (mainly in New Zealand) for the natural regeneration or seedling spread of introduced trees, occurring in locations not managed for forest production. The term is usually applied to members of the family *Pinaceae*, within which most of the major spreading forestry species of concern occur. Most wildings grow close to the parent seed source and are termed fringe spread. Wildings further afield are termed distant spread. They grow from seed often wind-blown from exposed take-off sites and usually occur as scattered outlier trees (Pringle & Willsman 2013). In New Zealand, wilding seedlings are considered vulnerable to grazing for the first 2 years. Mob stocking with sheep will significantly limit their spread, often to the extent that other control requirements are minimal. Cattle grazing is not as effective. Spread can be limited by oversowing and topdressing within a 200 m zone of spread-prone trees. This promotes increased grazing pressure on young wildings and helps the tussock grasslands compete strongly with germinating tree seedlings ("Wilding Prevention" by Nick Ledgard & Lisa Langer, Forest Research Institute, Box 29 237, Fendalton, Christchurch - http://ecan.govt.nz/advice/your-business/farming/Pages/wilding-trees-preventing-spread.aspx#techniques-prevent-spread).

pathogens, good germination and seedling establishment conditions), arrival of suitable symbionts (notably mycorrhizae) to aid early establishment, and climatic change to conditions more suited to the planted alien trees (Despain 2001; Engelmark et al. 2001). Natural regeneration of alien conifers is considered desirable in some instances. For example, evolving forest policy in Great Britain requires "lower impact silvicultural systems" on suitable sites that do not require large-scale clearfelling. The transformation of large alien conifer plantations to mixed-aged stands depends to a large extent on natural regeneration (Malcolm et al. 2001). The ecology of natural regeneration, and therefore naturalisation and invasion, is thus a highly topical issue (Richardson & Rejmánek 2004). Natural establishment of *E. globulus* plants in Portugal was recently documented by Águas et al. (2014), Catry et al. (2015), Fernandes et al. (2016).

3.3.2 Establish or join a network of sentinel sites

Planted forests of (invasive) alien trees should form part of any sentinel site network[44] for monitoring alien tree invasions. Other areas that are likely to act as sources of propagules and sites of entry for new invasions are areas of human habitation where gardens have been established (Alston & Richardson 2006), and experimental plantings, arboreta or botanical gardens containing (invasive) alien tree species. They can be included, as well, in sentinel networks.

Visser et al. (2014) have shown that Google Earth can be a useful tool for establishing a global sentinel site network for alien tree invasions, because imagery is continuously being updated, it is free and low-tech. In addition, the popularity of Google Earth could enable monitoring of this network of sentinel sites as part of a "citizen science" effort (Silvertown 2009). Data sharing via KML files is simple and would allow for easy sharing of locations of sentinel sites. In addition, Google Earth already has the capacity for users to upload photographs (via Panoramio; www.panoramio.com), which would allow for more accurate species identification and verification.

Visser et al. (2014) believe that such a sentinel site network could help to: (1) identify emerging trends in alien tree invasions; (2) provide valuable locality information for particular alien tree species; (3) monitor changes in alien tree species abundance and distribution over time; (4) help ensure legislative compliance of land managers and plantation owners; and (5) track management efforts over time.

In addition to alien tree sentinel sites, new technologies such as smartphone application software (apps) are increasingly used to reach a wider audience on the subject of invasive alien species and to involve the public in recording them (Adriaens et al. 2015).

[44] The idea of having a network of sentinel sites for monitoring or detecting biological changes or phenomena is not new and has been most widely applied to monitoring the spread of infectious diseases (e.g., Sserwanga et al. 2011; Vettraino et al. 2015), but has also been advocated for detecting the arrival or initiation of spread of invasive alien species (Richardson & Rejmánek 2004; Meyerson & Mooney 2007) and a national system for detecting emerging plant invasions in the United States was proposed (Westbrooks 2003), but has yet to be enacted (Visser et al. 2014). The idea behind most sentinel networks is to have a relatively small number of sites spread across a broad, but defined geographical area, at which detailed analyses can be made in order to detect the biological change or phenomenon in question or to indicate changing trends which could trigger management interventions. Such a network, at the global scale, has previously been proposed ''to monitor reproduction and regeneration dynamics of alien species'', especially alien tree species growing in planted forests or arboreta (Richardson & Rejmánek 2004). The amount of introduction effort, which ultimately contributes to the amount of propagule pressure, has been identified as a principal driver of new invasions as have sites of likely entry for an invasive species. *Cf.* also Richardson & Rejmánek (2011); Dodet & Collet (2012).

3.4 Outreach

3.4.1 Engage with the public on the risks posed by invasive alien trees, their impacts and on options for management

The general public is a very important stakeholder group in national issues of forests and forestry[45]. The active and informed participation of communities and stakeholders affected by planted forest management decisions is critical to the credibility and sustainability of management processes. Public awareness-raising and communication activities play a critical role in informing and educating the public[46], thereby allowing them to more effectively participate in decision-making. Public support for control efforts directed at invasive alien trees 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 infestations, and the effective use of media outlets.

Forestry has become more complex over the years. This form of land use now benefits a wider stratum of people and environments than ever before, and is subject to a large range of social and environmental demands. As a result, the need for a wide range of professional and managerial skills has increased.

Furthermore, 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 non-native tree species, restoration actions, wildlife and landscapes, how they function and how they came to be. In addition, visitors are also likely to be interested in the lifestyles, cultures and social and political histories of local communities living near forest areas and planted forests.

3.5 Forward Planning

3.5.1 Consider developing research activities on invasive alien trees species and becoming involved in collaborative research projects at national and regional levels

Invasion biology is a complex multidisciplinary field and public and private planted forests of alien trees are good places to conduct research on topics such as the naturalisation, spread, control, management

[45] (e.g., Janse 2008; Hemström et al. 2014) A mail-in questionnaire was used to investigate public perceptions and acceptance of intensive forestry practices in Sweden. The results showed that although a majority of the general public in Sweden supports measures to increase forest growth, they oppose the use of intensive forestry practices such as the cultivation of exotic tree species, clones, and forest fertilization. The acceptance of such practices is mainly influenced by the perceptions of their environmental consequences. Public acceptance was highest for forest fertilization, whereas clone cultivation was the least accepted practice. The greater acceptance of the cultivation of exotics in southern Sweden than in the more forestry-dependent north, may relate to the greater variety of tree species in the south. This regional difference is consistent with earlier results that attitudes towards forests and forestry vary between regions (Hemström et al. 2014).

[46] In Portugal, even though invasive alien species, e.g. acacias, are recognized as a threat to biodiversity by law, the majority of the population is unaware of this problem. Aiming to increase awareness about biological invasions among young students, a workshop on Invasive Plant Species was organized at the Botanical Museum of the University of Coimbra. A total of 170 students from five schools participated in the workshop. Three activities were prepared, focusing on: (1) identification of invasive plants, (2) competition between native and invasive plants and (3) control of invasive plants. A year later, questionnaires were sent to the participants to appraise the effectiveness of the workshop. It revealed that the students know more about invasive plant species than a comparable group of students who did not participate in the workshop. The results clearly showed that practical informal education activities may be effective in raising public awareness. Questionnaires were essential to evaluate the knowledge acquired and retained by the students during the workshop (Marchante et al. 2010; Schreck Reis et al. 2011). See also Andreu et al. (2009); McNeely (ed.) (2001).

and risks posed by invasive alien trees in collaboration with national or local environment agencies, research centres and appropriate regional or European bodies[47].

Great Britain, for instance, with its long history of tree introductions and large plantings of many alien tree species (e.g. *Picea sitchensis*, the commonest British tree; Peterken 2001), is a good natural laboratory for studies of the determinants of naturalisation and invasion in conifers and its consequences (Richardson & Rejmánek 2004).

It would also be very informative to revisit as many sites as possible in Europe where many alien tree species were planted long ago, e.g. the experimental plantings of many conifers in Italy (Nocentini 2010), Portugal and Spain, and abandoned plantations (Richardson & Rejmánek 2004).

3.5.2 Take global change trends into consideration

Forest management and conservation are expected to be strongly influenced by global change and climate change. Besides forest species, strategies and references for management and conservation will be affected by global change trends[48]. For example, rapidly changing climate patterns, altered disturbance and nutrient regimes, and increased fragmentation are very likely to favour considerable expansion of alien pine invasions worldwide (e.g., Higgins & Richardson 1999; Richardson & Rejmánek 2004).

Bernier and Schoene (2009) propose three possible approaches for adapting forests to climate change: no intervention, reactive adaptation and planned adaptation[49]. When applied to planted forests of (invasive) alien trees no intervention would means business as usual, with alien tree species selection, management targets and practices based on the premise that the planted forest will adapt more or less as it has in the past. Reactive adaptation is action taken after the fact. Planned adaptation, on the other hand, involves redefining forestry goals and practices in advance in view of climate change-related risks and uncertainties. It involves deliberate, anticipatory interventions at different levels and across sectors.

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[47] E.g., the FPS COST Action FP1403 Non-native tree species for European forests - experiences, risks and opportunities (NNEXT) [http://www.cost.eu/COST_Actions/fps/Actions/FP1403]; the project INVASIVE, Introduced tree species in European forests [http://www.eficent.efi.int/portal/projects/invasive/]. INVASIVE is funded by the German Federal Ministry for Food and Agriculture (BMEL) and co-ordinated by the staff at the European Forest Institute (EFI) at the Central European regional office EFICENT. The partners on the project include FVA Baden-Württemberg, IRSTEA, University of Freiburg, WSL Switzerland and Belgian Biodiversity Platform amongst others. The FA COST Action TD1209 European Information System for Alien Species [http://www.cost.eu/COST_Actions/fa/Actions/TD1209] does not specifically address invasive alien trees, but aims to facilitate enhanced knowledge gathering and sharing through a network of experts, providing support to a European IAS information system which will enable effective and informed decision-making in relation to IAS. An overarching priority will be to identify the needs and formats for alien species information by different user groups and specifically for implementation of EU 2020 Biodiversity Strategy. See also: the FPS COST Action FP1002 Pathway Evaluation and pest Risk Management In Transport (PERMIT) [http://www.cost.eu/COST_Actions/fps/Actions/FP1002].

[48] *Cf*., Jackson et al. (2005); Aitken et al. (2008); Canadell & Raupach (2008); Diaz et al. (2009); Heller & Zavaleta (2009); Thompson et al. (2009); Strassburg et al. (2010); Milad et al. (2013).

[49] In the framework of SFM adaptation to climate change is the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation". Ecosystem-based adaptation to climate change is an adaptation strategy that includes ecosystem management, conservation and the restoration of ecosystems to provide services that help people adapt to adverse impacts of climate change. Cf. also McCarthy et al. (2001); Locatelli et al. (2008); CBD Secretariat (2009). Connecting biodiversity and climate change mitigation and adaptation: report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change. Technical Series No.41. CBD Secretariat, Montreal, Canada.

In planted forests, climate change could affect the dynamics of alien[50] tree invasions in many interacting ways, for example: (a) by causing modification in the native ecosystems promoting range changes, naturalisation and spread of both native and alien trees (e.g., Iverson et al. 2008; McKenney et al. 2011); (b) by favouring individual traits of particular alien trees (e.g. Capdevila-Argüelles & Zilletti 2008; Kawaletz et al. 2013; Castro-Díez et al. 2014); and (c) by modifying introduction pathways and promoting a larger use of certain alien trees (Courbet et al. 2012; Lindenmayer et al. 2012) including a process of re-thinking the importance of the "always choosing native species" principle (UK Forestry Commission[51]). Managed relocation[52] has 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).

Discussion is intensifying in many countries on whether and, if so, then to what extent alien tree species should be taken into account for planted forests, especially when native species are no longer able to fulfil essential forest functions. For example, in this regard, for the first time the growth potential of *Cedrus libani* was evaluated under climatic conditions in Central Europe (Bayreuth, Germany) by Messinger et al. (2015).

Finally, it is important to incorporate climate change into risk assessment and risk analysis models for an anticipatory evaluation of scenarios for invasiveness of alien trees. Risk maps[53] that incorporate the effects of climate change should help land managers and forest stakeholders with longer-term planning activities. Management plans of nature reserves should incorporate changes to invasion risk driven by global warming more explicitly[54].

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[50] In accordance with the Recommendation No. 142 (2009) of the Standing Committee, adopted on 26 November 2009, interpreting the CBD definition of invasive alien species to take into account climate change, the term "alien tree species" for the purpose of this Code of Conduct does not include native tree species naturally extending their range in response to climate change.

[51] http://www.forestry.gov.uk/pdf/eng-trees-and-climate-change.pdf/$FILE/eng-trees-and-climate-change.pdf. See also Forestry Commission (2011); NOMADES, *NOuvelles Méthodes d'Acclimatation Des Essences forestières* (http://www.reseau-aforce.fr/nomades-437950.html - http://www.reseau-aforce.fr/data/info/497950-NOMADES_Fascicule1_Bilan_introduction_vdef_fev15.pdf); REINFFORCE, REsource INFrastructures for monitoring, adapting and protecting european atlantic FORests under Changing climatE (http://www.iefc.net/?affiche_page=projet_REINFFORCE&langue=en)..

[52] 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).

[53] Pest risk maps are powerful visual communication tools to describe where invasive alien species might arrive, establish, spread, or cause harmful impacts. These maps inform strategic and tactical pest management decisions, such as potential restrictions on international trade or the design of pest surveys and domestic quarantines. Diverse methods are available to create pest risk maps, and can potentially yield different depictions of risk for the same species (Venette et al. 2010).

[54] For example, Kleinbauer et al. (2010) suggest that the area suitable for invasions by *Robinia pseudoacacia* will increase considerably in Europe under a warmer climate. They argue that management plans for European nature reserves should incorporate changes to invasion risk by species such as this one through global warming more explicitly. Reducing propagule pressure by avoiding plantings of *R. pseudoacacia* close to protected areas endangered habitats would be a simple way of reducing the risk of further invasions of this alien species under future climates. North American feltleaf willow (*Salix alaxensis*), recently introduced as a forestry species in Iceland, has become naturalised and started to spread very effectively. It seems that the spread of this alien tree species will be further facilitated by climate change (Wasowicz et al. 2013). On the contrary, González-Muñoz et al. (2014) did not predict an enhancement of *Acacia dealbata* growth along this century. They also did not predict a marked decline of this species, which means that climate change alone will not stop or modify the spread of *A. dealbata* in Spain.

4. Background information: a knowledge basis for the Code of Conduct

4.1 Benefits arising from planted forests and planted forests of alien trees

Planted forests do not purport to provide the full array of social, environmental and economic functions of indigenous forest. They can take over many, though not all, functions that indigenous forest provide (FAO 2010c).

Planted forests designed to provide multiple ecosystem services can reduce pressure on natural forests, and can even restore some ecological services provided by natural forests. They can also play a key role in the fight against global warming, through carbon sequestration. Paquette & Messier (2010) reviewed the economic, social, and environmental services that plantations can provide, and make a plea for the implementation of well-conceived, diverse, multi-purpose plantations as a way to conserve forest biodiversity and ecosystem functions. Well-designed, multi-purposed planted forests can help mitigate climate change[55] through direct carbon sequestration or by avoiding deforestation, while simultaneously protecting remaining natural forests through increased productivity.

Standards, guidelines, criteria and indicators for sustainable forest management (SFM) have been developed over the past few decades by intergovernmental processes, international organisations[56], certification schemes (e.g. FSC, PEFC) (Masiero et al. 2015) and national governments (Cf. Section 4.6.6 in this Code of Conduct). These apply to all forests, including planted forests, and have resulted in forestry being recognised as an essentially sustainable land-use and 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 European level, the 46 signatories of the Ministerial Conference on the Protection of Forests in Europe agreed 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 are regularly updated and adapted to new challenges[57]. Also the International Tropical Timber Organization ITTO has developed and is revising criteria and indicators for sustainable forest management since the early 1990's[58].

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[55] E.g., for France see Blondet M. (2015), Conflicting engagements on climate change adaptation in French private forest: an anthropological perspective. Document de travail du LEF n°2015-03 (LEF, AgroParisTech/INRA, Nancy, France). The issue of climate change is progressively entering the field of forest management in France and Europe. It poses significant questions to forest managers since forest management is made on a very long time scale. Decisions taken today will impact forest for many years and climate change may threaten these long term investments. According to scientists, beech forest is particularly sensitive to drought and may disappear in the coming years due to global warming. Beech is also one of the protected species in the Annexes of the Habitat Directive. To face and bring answers to this issue of the future of beech forest before this change in climate conditions various actors from the forest sector, the conservationist organisations and the policy-making sphere are engaging at the national level in France. Yet they carry different views of the issue. In France, and within that frame, a debate recently started around the possible use of planted forest of alien trees to control the impacts of climate change in forest. The idea basically is to seek for more resistant tree species in order to replace the weakest ones such as European beech. These stronger species are often not indigenous species, which may be subject to controversy among actors from the forest sector, the conservationist organisations and the policy-making sphere.

[56] *Cf.*, New Generation Plantations (NGP), 2014. New generation plantations: review 2014 (http://newgenerationplantations.org/multimedia/file/12b486cb-ea24-11e3-9f9e-005056986313).

[57] Forest Europe http://www.foresteurope.org/sfm_criteria/criteria

[58] ITTO http://www.itto.int/sustainable_forest_management/

Recognizing the economic, social, cultural and environmental importance of planted forests, governments and other stakeholders asked FAO to prepare, together with collaborating partners, a set of guiding principles in support of the policy, legal, regulatory and technical enabling conditions for planted forest management (FAO 2006b).

Since 1980, the Food and Agriculture Organisation of the United Nations (FAO) through its Forest Resources Assessments (FRA), has been collecting data on forest areas for two main categories of forests: natural forests and **forest plantations**[59]. In 2005, the FRA introduced two additional forest categories: modified natural forests and semi-natural forests (Evans 2009a), which resulted in five major forest categories based on the degree of human intervention and the silvicultural methods of forest regeneration. These include (1) primary forest; (2) modified natural forest; (3) semi-natural forest, comprising natural and planted regeneration (SNPF); (4) plantations comprising productive and protective plantations; and (5) trees outside forests (Payn et al. 2015). Productive and protective plantations, together with SNPFs, constituted the subgroup "**planted forests**"[60] (FAO 2010a). In the Global Forest Resources Assessment 2010 (FAO 2010a) the concept of "planted forests" was defined more broadly than the concept of forest plantations as used in previous global assessments. This change was made to capture all planted forests and is in line with the recommendations of the Global Planted Forests Thematic Study 2005 (FAO 2006a) and recent efforts to develop guidelines and best practices for the establishment and management of planted forests. The FRA 2015 definition (FAO 2012) refined this to: forest predominantly composed of trees established through planting and/or deliberate seeding, where the planted/seeded trees are expected to constitute more than 50 % of the growing stock at maturity. They include coppice from trees that were originally planted or seeded and rubber wood, cork oak and Christmas tree plantations (Payn et al. 2015).

East Asia, Europe and North America hold the greatest area of planted forests, together accounting for about 75 % of global planted forest area, followed by North America and Southern and Southeast Asia (FAO 2010a; Payn et al. 2015). In East Asia planted forests make up 35 % of the total forest area; most of these are found in China. The second largest area of planted forests is found in Europe, although the share of planted forests here is close to the world average. However, if the Russian Federation with its vast area of natural forest is excluded from Europe, the share of planted forests in Europe increases to 27 %, the second highest proportion in the world. North America has the third largest area of planted forests with 5.5 % of the total forest area occurring in this subregion. Subregions reporting the smallest area of planted forests are the African subregions, the Caribbean, Central America and Western and Central Asia. In most subregions, the majority of the planted forests are found in just a few countries. For instance, in northern Africa 75 % of the planted forest area is located in Sudan, in East Asia, 86 % is found in China. Some arid-zone countries (Cape Verde, Egypt, Kuwait, Libyan Arab Jamahiriya, Oman, United Arab Emirates) and the Netherlands report that all their forests have been established through planting or deliberate seeding (FAO 2010a).

Between 2000 and 2010, the area of planted forest increased by about 5 million ha per year (FAO 2010a), with a further increase in the period 2010-2015 (Payn et al. 2015; FAO 2015b). Most of this was established through afforestation, particularly in China.

[59] In the FAO FRA 2000 (FAO 2001) "forest plantations" were defined as those forest stands established by planting or/and seeding in the process of afforestation or reforestation. They comprised either native or non-native species which met a minimum area requirement of 0.5 ha; tree crown cover of at least 10 % of the land cover; and total height of adult trees above 5 m.

[60] In Annex 2, "Terms and definitions used in FRA 2010" page 212, *planted forest* is defined as follows: Forest predominantly composed of trees established through planting and/or deliberate seeding; the sub-category *planted forest of introduced species* as planted forest, where the planted/seeded trees are predominantly of introduced species.

4.2 Alien tree species in Planted Forests: historical and recent pathways of introduction

4.2.1 General aspects

As stated in Section 1, in accordance with the CBD and the Reg. (EU) No. 1143/20014, the term alien is used throughout this Code of Conduct. It has the same meaning as exotic, introduced and non-native. In accordance with the CBD definition, the term alien has exclusively a biogeographical meaning, i.e. it refers to a tree species, subspecies or lower taxon (including provenance), introduced by man outside its natural past or present distribution.

After the United Nations Conference on Environment and Development (UNCED) in 1992, known as the Rio Summit, an enhanced understanding of sustainable forest management (SFM) has entered the stage of forest policy worldwide (Wolfslehner et al. 2005; *Cf.* Section 4.6.6 in this Code). Key outcomes of the conference were the "Forest Principles" and the Chapter 11 of Agenda 21 of the conference's action plan (UNCED, 1992a, 1992b, 1992c) which detailed the international commitments to the sustainable development of forests, and called for the formulation of scientifically sound criteria and indicators (C&I) for sustainable forest management (Baycheva-Mergera & Wolfslehner 2016).

However, in addition to the use in planted forests, alien tree species have been and are introduced and used for various and multiple reasons (i.e. introduction pathways[61]), such as gardening, protective functions, arboreta, erosion protection and for increasing the forest area through afforestation of abandoned or derelict land.

In the 2010 FAO Global Forest Resources Assessments (FAO 2010a) countries reported on the use of *introduced*[62] tree species in the establishment of *planted forests of introduced species*. Globally, of the 233 countries and areas included, only 117[63] countries reported on the use of *introduced* species, while the remaining 116 countries and areas did not report on the use of *introduced* species.

At the global level, *introduced* tree species grow on about a quarter of the planted forest area of the countries for which data were reported (FAO 2010a). Payn et al. (2015), using FRA 2015 datasets (FAO 2015a, 2015b), estimated that only between 18% and 19% of the planted forests comprise *introduced* tree species. There are marked differences between and within regions. South America, Oceania, and East and Southern Africa are the regions dominated by plantings of *introduced* tree species, with large percentages

[61] The term **pathways** in used in accordance to the CBD definition, i.e. UNEP/CBD/SBSTTA/18/9/Add.1 of 26 June 2014, Pathways of Introduction of Invasive Species, their Prioritization and Management (https://www.cbd.int/doc/meetings/sbstta/sbstta-18/official/sbstta-18-09-add1-en.pdf). The Guiding Principles for the Prevention, Introduction and Mitigation of Impacts of Alien Species that threaten Ecosystems, Habitats and Species (the Guiding Principles) annexed to decision VI/23, provide all Governments and organizations with guidance for developing effective strategies to minimize the spread and impact of invasive alien species. In particular, the Guiding Principles highlight the importance of identifying pathways of introduction of invasive species in order to minimize such introductions, and call to assess the risks associated with such pathways. Furthermore, Aichi Biodiversity Target 9 specifies: "By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment".

[62] The 2010 FAO Global Forest Resources Assessments uses the term "introduced". The definition of "introduced species" is as follows: a species, subspecies or lower taxon, occurring outside its natural range (past or present) and dispersal potential (i.e. outside the range it occupies naturally or could occupy without direct or indirect introduction or care by humans). The FAO 2015 Global Forest Resources Assessment (FRA), defines an introduced species as a species, subspecies or lower taxon, occurring outside its natural range (past or present) and dispersal potential, i.e. outside the range it occupies naturally or could occupy without direct or indirect introduction or care by humans, FAO (2012). In FRA 2015 the term introduced is considered equivalent to non-native.

[63] Seventeen countries reported that they have not used introduced species in the establishment of planted forests (FAO 2010).

of plantings comprising *introduced* tree species. North America, West and Central Asia, and Europe are at the other end of the spectrum with 1%, 3% and 8% of the area planted in *introduced* tree species Payn et al. (2015).

In eastern and southern Africa, most planted forests consist of *introduced* tree species in the genera *Eucalyptus*, *Pinus*, *Hevea*, *Acacia* and *Tectona*, chosen for their ability to grow in many environmental conditions and to rapidly produce wood or other economic products (e.g., gum Arabic, rubber) (FAO 2010a).

Planted forest species in Oceania and in South America (Argentina, Bolivia, Brazil, Chile, Ecuador and Uruguay) also comprise *introduced* tree species. Oceania has a long history of planted forest management due to historic wood supply deficits and offers excellent growing conditions for a number of fast growing species, among them *Eucalyptus* spp., *Pinus radiata* (Monterey Pine), *Pseudotsuga menziesii* (Douglas-fir) and *Cupressus* spp.[64]. South America is encouraging the use of intensively managed short-rotation *introduced* tree species such as *Eucalyptu*s spp., *Pinus radiata*, *P. taeda*, *P. elliottii* and *Tectona grandis*.

In East Asia, China uses *introduced* tree species on 28 % of the planted forest area while Japan did not report the proportion of *introduced* tree species (FAO 2010a, 2015a). In South and Southeast Asia, a number of countries with a significant area of planted forest did not report on the use of *introduced* tree species (Indonesia, Malaysia and Vietnam[65]). In Southeast Asia, plantations are established more for non-timber crops than timber, particularly coconuts, rubber, and oil palm (Corlett 2005) but there is a growing interest for *Acacia* and *Eucalyptu*s plantations (Harwood & Nambiar 2014).

In western and central Asian countries (e.g., Turkey[66] - 59,000 ha, FAO 2015a) the use of *introduced* tree species is very low, while other countries in this subregion did not report on *introduced* tree species. In the temperate and boreal regions of Europe and North America and in the arid zone countries of northern Africa *introduced* tree species are only used to a minor extent.

Some parts of Europe lack highly productive native tree species with timber or growth characteristics suited to planted forests, and foresters rely largely upon non-native tree species. These alien tree species can be established easily on certain sites, have better growth rates than native species, broader physiological adaptability with regard to site conditions including drought tolerance (Savill et al. 1997). The area dominated by *introduced* tree species covers about 9 million has or 4 % of the total forest area (without the Russian Federation). In the Russian Federation less than 100,000 ha of its vast forest area was reported as planted forest with non-native trees, thus being negligible (66,000 in 2015, FAO 2015 a). In Denmark, Iceland and Italy[67], *introduced* tree species are reported to occur also on other wooded land (Forest Europe, UNECE and FAO 2011).

The most important alien tree species used in Europe for timber production include *Pseudotsuga menziesii*, *Picea sitchensis*, *Pinus contorta*, *Larix* spp., *Populus* hybrids and clones, and a number of *Eucalyptus* spp. The relative absence of pests and specialised grazing or defoliating insects from aliens allows the trees to grow much faster than native species until pests catch up with their hosts, especially if unaccompanied by their natural enemies (Savill et al. 1997). However, when plantation alien trees are

[64] *Cupressus macrocarpa*, *C. lusitanica*, and the closely related *C. benthamii*.
[65] According to IUFRO (Scientific Summary No 120, related to IUFRO News 4, 2014), the most significant areas of plantations of Australian Acacias are in SE Asia where *A. mangium*, its hybrid with *A. auriculiformis* and *A. crassicarpa* are the main taxa. In Vietnam over 1M ha of Acacia plantations supply a burgeoning furniture manufacturing industry as well as the export woodchip market.
[66] The Strategic Plan of the General Directorate of Forestry (2013-2017) is a commitment to industrial plantations with fast growing species. It is planned that industrial plantations are established in a total area of 15,000 ha by the end of 2014 (Deniz & Yildirim 2014).
[67] Between the 1920 and the 1939, 450 experimental plots for 124 non-native tree species where established in Italy with the purpose of comparing their productivity performances (Pavari & De Philippis 1941; Nocentini 2010).

reunited with their coevolved pests, which may be introduced accidentally, or when they encounter novel pests to which they have no resistance, substantial damage or loss can ensue. The longer these non-native trees are planted in an area, the more threatened they become by native pests (Wingfield et al. 2015).

In Sweden, Elfving & Norgren (1993) have demonstrated that *Pinus contorta*[68] (lodgepole pine) can grow 32 % faster in terms of stemwood volume than the native *P. sylvestris* (Scots pine), because the former allocates more resources to the growth of stems and fine roots rather than larger roots compared to the latter (Savill et al. 1997). Other reasons for the superior growth of lodgepole pine under boreal conditions may be an earlier start of growth in spring and a lower required heat sum to start shoot elongation compared to Scots pine (Fedorkov 2010; Backlund & Bergsten 2012). Despite the apparent growth, and hence economic, benefits of alien tree species, fears of eventual pest and disease outbreaks led to legislation in 1979 (Swedish Forestry Act) and in 1992 aimed at limiting the use of *P. contorta* until the potential risks are better understood (Savill et al. 1997).

Pseudotsuga menziesii was introduced to Europe from North America more than 150 years ago[69], and is now the most economically-important alien tree species in European planted forests (Schmid et al. 2014). It was introduced to Sweden in the 1920s, and planted forests are currently estimated to occupy approximately 500 ha, primarily on large estates in southern Sweden (Felton et al. 2013). Broncano et al. (2005) described the naturalisation by *Pseudotsuga menziesii* in Montseny Natural Park (Catalonia, NE Spain – a declared a UNESCO Biosphere Reserve in 1978). Establishment of seedlings started 15 years after plantings. Essl (2005) reports the naturalisation of *Pseudotsuga menziesii* in lowland northeastern Austria, and there are naturalised occurrences in most other Central European countries (Schmid et al. 2014)[70].

Northern red oak (*Quercus rubra*) is an economically important, moderately shade-tolerant tree species native to eastern North America (Sander 1990). While this species is failing to regenerate in many locations in its native range, red oak has regenerated readily in Central European forests since its introduction in the mid-18th century (Kuehne et al. 2014). The ability of non-native red oak to perform equally well to native shade-tolerant species under a variety of light conditions could contribute to the consistent success of red oak regeneration in Europe (Riepšas & Straigitė 2008; Kuehne et al. 2014; Woziwoda et al. 2014).

Robinia pseudoacacia has been widely used for various purposes such as ornamentation, timber, firewood, re-vegetation of dry land, soil stabilisation and providing nectar for honey production (EEA 2008). *Robinia pseudoacacia* stands occupy 20 % (about 400,000 ha) of the Hungarian forest area (Rédei 2002; Rédei et al. 2011b), and it has been documented that it is invading a range of high nature value habitats in continental temperate Central Europe (Kleinbauer et al. 2010)[71]. Having only one native species, downy birch (Betula pubescens), and a small forest area, Icelandic forests have a high proportion of *introduced* tree species due to afforestation efforts.

[68] *Pinus contorta* Dougl. var. *latifolia* Engelm.
[69] David Douglas introduced *Pseudotsuga menziesii* to Great Britain in 1827 (Gellini & Grossoni 1996).
[70] *Cf.*: Tschopp, T., Holderegger, R., Bollmann, K., 2014: Auswirkungen der Douglasie auf die Waldbiodiversität : Eine Literaturübersicht. WSL Berichte, Heft 20, 2014 (55 S.); Tschopp, T., Holderegger, R., Bollmann, K., 2015: Auswirkungen der Douglasie auf die Waldbiodiversität. Schweiz. Z. Forstwesen 166 (2015) 1: 9-15: Vor, T., Spellmann, H., Bolte, A., Ammer, C. (Hrsg.), 2015: Potenziale und Risiken eingeführter Baumarten. Baumartenportraits mit naturschutzfachlicher Bewertung. Deutscher Verband forstl. Forschungsanstalten, 2015 (233 S.): http://www.dfwr.de/aktuelles/ -> Rubrik "Aktuelles aus der Forstwirtschaft", Mitteilung vom 23. Februar 2015, Dokument Nr 5.
[71] Pure or mixed stands of *Robinia pseudoacacia* now cover some 200,000 ha in France, 250,000 ha in Romania and 230,000 ha in Italy (Sitzia 2014).

Sitka spruce (*Picea sitchensis*) from North America is the most common alien tree in Great Britain and Ireland (Peterken et al. 1992; Quine & Humphrey 2010; Peterken 2001). Britain has a very limited native tree flora, but now has a great variety of *introduced* trees (Peterken 2001). The most commonly used alien coniferous trees are *Abies alba*, *Larix decidua*, *Picea abies*, *Picea sitchensis*, *Pinus contorta*, *Pseudotsuga menziesii*, *Tsuga heterophylla*. *Introduced* trees have formed hybrids in Britain, both with native trees and amongst themselves. *Quercus* × *turneri* (syn. *Quercus* × *hispanica*) is a semi-evergreen oak formed in the late 18th century by *Q. ilex* × *Q. robur*.

Ailanthus altissima, mainly used as an ornamental or for roadside plantings, is now one of the most widespread invasive alien plant species in Europe and North America (Sladonja et al. 2015). *Acer negundo* and *Prunus serotina*[72] are both ranked third and are reported as invasive alien trees in several European countries (Forest Europe, UNECE and FAO 2011).

A shift in forest management to increase the share of native tree species has led to a steady decline of introduced tree species (e.g., in the Netherlands). Countries with a very low share, i.e. below 0.5 %, of introduced tree species or no introduced tree species are Lithuania, Finland, Estonia, Serbia, Latvia, Belarus, Liechtenstein and Georgia (Forest Europe, UNECE and FAO 2011, 2015a).

4.2.2 Alien conifers

Many alien conifers are very widely used in planted forests, and as amenity and ornamental plants (Richardson & Rejmánek 2004). *Pinus radiata*, from a tiny native range in California and a few islands, has been planted over huge areas in alien plantations, mostly in the southern hemisphere, especially New Zealand, Chile, Australia and South Africa. A total number of 38 Conifers are listed in the global database of invasive trees and shrubs (Rejmánek & Richardson 2013), with 15 of them indicated as invasive also in Europe[73].

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[72] *Prunus serotina* (syn. *Padus serotina*), a forest tree of North American origin (Mexico-Guatemala to south-east Canada), was introduced to central Europe and planted for various purposes. The first record of the species in Europe dates back to 1623 when the tree was planted for ornamental purposes near Paris (Starfinger 1997), in England in 1629 and in Germany in 1685 (Starfinger & Kowarik 2003), where it was particularly appreciated as an ornamental (Petitpierre et al. 2009). Between 1900 and 1930, black cherry was planted for multiple uses such as wind and firebreaks, to improve soils under coniferous plantations, or for shelter (Pairon et al. 2010; Vanhellemont et al. 2010). It was first considered a valuable timber tree by European foresters, then a useful non-timber species in forestry, then a forest pest, a controllable weed, an invasive alien tree and, eventually, a species we have to live with. All these perceived qualities served as motives for action by humans often without seeking scientific evidence for them: millions of specimens of *P. serotina* were planted. Later millions of Euros were spent in attempts at control (e.g., Van den Meersschaut & Lust 1997). The overall loss to the German economy through yield reduction and control costs was estimated at 25 millions of Euros per year. A similar figure was estimated for the Netherlands (Starfinger 2010). The species, and its changing perception through time, may be an example of the need for science-based assessments as a basis for developing policies concerning the use of non-native tree species in planted forests (Starfinger et al. 2003). In Italy, the Lombardy Region warns about the risks posed by *Prunus serotina* in planted forests (http://www.arpalombardia.it/biodiversita/piante-viaggiatrici/landing-schede/prunus-serotina.html). According to the most recent studies, *Prunus serotina* grows spontaneously in many European countries from France to Poland and Romania as well as from Denmark to Italy. It is spreading throughout temperate forests in north-western Europe, especially on well-drained poor soils. This tree is now considered as one of the 100 most invasive alien species in Europe (DAISIE, 2009). *Prunus serotina* competes for resources with native plant species, especially during forest regeneration and under high herbivore pressure. Invaded stands have higher levels of phosphorus, a shallower litter layer, and lower pH values than non-invaded stands. Shading out light-demanding species, especially seedlings of other tree species, it can impede natural regeneration of native tree species and induces a decrease in species richness, mainly in disturbed stands. Fruits are produced in high quantities and are well dispersed, mainly by birds. More than 50% of the seeds are dispersed at higher distances than 50 m; the average dispersal distance being estimated to 257 m (Pairon et al. 2010 and references cited therein).

[73] See also: Carrillo-Gavilán and Vilà (2010).

Picea abies is the most widely planted conifer in Europe and the most widely cultivated spruce in North America, and *P. sitchensis* is the commonest tree in Great Britain and Ireland. In general, conifer taxa from Europe and North America have been more widely planted well outside their natural ranges than those from other regions, notably Asia (Richardson & Rejmánek 2004 and references cited therein). An example is *Picea asperata* and its close relative *P. abies*. *P. asperata* (from China) has enjoyed trivial planting and dissemination outside its range compared to the European *P. abies*. Several *Pinus* species are among the most widespread and influential of all invasive alien trees, especially in the southern hemisphere (Richardson & Rejmánek 2004).

There are 56 non-native coniferous species recorded in Denmark. Seven of these are regarded as invasive and they are already on the Black list (see Annex 6.2). All were introduced intentionally for forestry and horticulture (Madsen et al. 2014).

Norwegian forestry has mainly used two native coniferous tree species, *Picea abies* and *Pinus sylvestris*, although attempts have been made to plant alien tree species, some of which are in current use (Felton et al. 2013). All alien tree species that have been planted have produced seed, and many have spread to a lesser or greater degree outside plantations. Only 4–5 of these alien species are considered as problem species to any degree, yet the fact that they can alter the environment rather dramatically where they become established means that they can locally, and perhaps also regionally, have marked impacts on biodiversity (Gederaas et al. 2012). The introduced species include *Picea sitchensis*, *Tsuga heterophylla*, *Pinus contorta*, *Larix decidua* and *Pinus mugo*. One of the species which is considered to have a severe impact (SE) is *Picea sitchensis*, and it is included in the Norwegian Black-List (see Annex 6.2).

The North American tree *Pinus contorta* var. *latifolia* was experimentally introduced to Sweden as early as the 1920s, and has been used in Swedish forestry on a large scale since the 1970s. Plantations of this species now cover 475,000 ha (with at least 65% Lodgepole pine), mainly in the northern part of the country (Engelmark et al. 2001; SLU 2010).

In Iceland, due to the lack of native trees suitable for planted forests, alien tree species (and conifers in particular) are economically important. Numerous conifers were introduced and are in use in Icelandic forestry, but *Pinus contorta* and *Picea sitchensis* have already become naturalised and started to spread outside cultivation (Wasowicz et al. 2013).

4.2.3 Alien eucalypts

Over 800 species of eucalypts (the genera *Angophora*, *Corymbia* and *Eucalyptus*) are native to Australia and a few Pacific islands. These genera include some of the most important solid timber and paper pulp alien forestry trees in the world. Besides pines, eucalypts are the most commonly and widely cultivated alien trees. Over 70 species are naturalised alien (reproduce and maintain their populations) outside their native ranges. However, given the extent of their cultivation, eucalypts are markedly less naturalised and lees invasive than many other widely cultivated alien trees and shrubs. Reasons for this relatively low invasiveness are not completely understood (Rejmánek & Richardson 2011; Rejmánek and Richardson 2013; Águas et al. 2014; Catry et al. 2015; Lorentz & Minogue 2015).

Eucalypts have been planted for forestry over large areas in Spain and Portugal, and to a more limited extent in Italy and Turkey. In Spain slightly more than 3.5 % of the total forestry area (Anuario de estadística forestal 2011) and in Portugal about 812,000 ha (Inventarío Florestal Nacional 5, 2005-06, 2013) are covered by *Eucalyptus* species (Forest Europe, UNECE and FAO 2011).

Nine eucalypt species are listed in the global database of invasive trees and shrubs according to Rejmánek & Richardson (2013), and two species have been recorded as naturalised alien in Europe (*E. camaldulensis* and *E. globulus*) (e.g. Catry et al. 2015).

4.2.4 Alien acacias

Like pines and eucalypts, many acacias (a polyphyletic group comprising more than 1,350 species, according to Maslin et al. 2003), and especially Australian acacias, have been widely planted outside their natural ranges for centuries (Richardson et al. 2011; Kull et al. 2011). Alien acacias besides being commercially important crops, play diverse roles in the lives and livelihoods of rural communities around the world. Landscapes in many parts of the world are dominated by planted or self-sown stands of Australian acacias. Some species are crops of major commercial importance and many others have considerable value for a wide range of purposes. Some Australian acacias are among the most widespread and damaging of all invasive alien plants (Richardson & Rejmánek 2011). Others are only moderately invasive, and yet others are not known to invade, although some of the last-mentioned are recent introductions.

A. melanoxylon was introduced in Portugal as an ornamental in the mid-nineteenth century and its expansion occurred in the first half of the twentieth century through national forestation programmes, in which the afforestation projects of coastal dunes included aliens such as *Acacia*, *Casuarina* and *Eucalyptus* (Goes 1991; Leite et al. 1999; Knapic et al. 2006). In Spain, *A. melanoxylon* is currently widely naturalised in Galicia, northern Spain, in areas below 500 m altitude, usually in low sloping lands (Sanz-Elorza et al, 2004). *Acacia dealbata* is on the Black List for Spanish mainland, and *A. farnesiana* and *A. salicina* for Canary Islands[74]. *Acacia dealbata* has become a serious environmental problem in Northwest Spain, where its expansion is assumed to reduce populations of native species and threaten local plant biodiversity (Lorenzo et al. 2010, 2011).

A total of 33 species in the genus *Acacia* are listed in the global database of invasive alien trees and shrubs (Rejmánek & Richardson 2013); 9 species are known to be invasive alien in Europe (8 taxa from Australia and one from Africa)[75].

4.2.5 Alien poplars and willows

An estimated 70 countries grow poplars and willows in mixtures with other natural forest species, in planted forests and as individual trees in the landscape (including agroforestry systems). Country reports to the International Poplar Commission (IPC[76]) indicate that poplars and willows account for more than 95 million ha of natural (82 million ha) and planted forests and agroforestry production systems (13 million ha) globally. The Russian Federation, Canada and the United States have the largest reported areas of naturally occurring poplar and willows, while China, India and Pakistan have the largest planted areas (FAO IPC Website 2014[77]).

Poplars and willows are multi-purpose species and form an important component of forestry and agricultural production systems worldwide, often owned by small-scale farmers. They provide a long list of wood and fibre products (sawn lumber, veneer, plywood, pulp and paper, packing crates, pallets, poles, furniture and small handicraft), non-wood products (animal fodder), environmental services (rehabilitation of degraded lands, forest landscape restoration, climate change mitigation) and are grown increasingly in

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[74] *Real Decreto 630/2013, de 2 de agosto, por el que se regula el Catálogo español de especies exóticas invasoras* (Act 630/2013, 2nd August, that regulates Spanish Catalogue on Invasive Alien Species - http://www.boe.es/buscar/act.php?id=BOE-A-2013-8565). *Cf.* also García-de-Lomas & Vilà (2015).

[75] See also Pasta et al. (2012) for the Mediterranean region. Vietnam has over 400,000 ha of *Acacia* plantations, including over 220,000 ha of clonal *Acacia* hybrid (*Acacia mangium* × *Acacia auriculiformis*). *Acacia* hybrid has been planted extensively in the southern provinces of Vietnam, and is becoming one of the main species for industrial plantations (Sein & Mitlöhner 2011).

[76] The International Poplar Commission (IPC) is one of the oldest statutory bodies within the framework of the Food and Agriculture Organization of the United Nations (FAO). It was founded in 1947 by 9 European countries in the aftermath of WWII destructions, when poplar and willow culture was considered a priority to supporting reconstruction of rural and industrial economies (http://www.fao.org/forestry/ipc/en/).

[77] http://www.fao.org/forestry/ipc/69994/en/

bio-energy plantations for the production of biofuels. These attributes make poplars and willows ideally suited for supporting rural livelihoods, enhancing food security, alleviating poverty and contributing to sustainable land-use and rural development (FAO IPC Website 2014).

Transgenic poplars have been used in numerous regulated field trials in the USA and elsewhere (Strauss et al. 2004), and are currently being commercially cultivated in China (Sedjo 2005). There is a large potential for additional transgenic applications because the poplar genome has been sequenced, many genotypes are amendable to genetic transformation, and transformation appears capable of improving its high value for bioremediation as well as a number of other traits (Boerjan 2005; Di Fazio et al. 2012). Poplars are dioecious and wind-pollinated, and produce abundant, small seeds with cotton-like appendages that facilitate long-distance dispersal by wind and water. Finally, wild relatives are often interfertile with cultivated clones, and extensive wild populations commonly occur in the vicinity of commercial plantations (Di Fazio et al. 2012). There are substantial concerns about the spread of transgenic plants into wild and feral plant communities. These concerns are heightened for perennial species such as trees that have undergone little domestication and that provide extensive ecological services (James et al. 1998; Hoenicka & Fladung 2006; Di Fazio et al. 2012).

North American feltleaf willow (*Salix alaxensis*), recently introduced as a forestry species in Iceland, has become naturalised and started to spread very effectively. It seems that the spread of this species will be further facilitated by climate change (Wasowicz et al. 2013).

Five *Populus* and 14 *Salix* taxa are listed in the global database of invasive trees and shrubs (Rejmánek & Richardson 2013); three *Populus* (*P. alba, P.* × *canadensis, P.* × *canescens*) and two Salix taxa (*S. daphnoides*, *S. fragilis*) are listed as being invasive to and in Europe (i.e., although native in some parts of Europe).

4.2.6 Alien trees and plantations on disturbed land

Numerous industrial processes disturb land of which the principal ones are mining, extraction of sand, gravel and clay, rock and limestone quarries, deposition of waste products including landfill sites, road and railway construction. The greatest amount of dereliction occurs in industrial countries. The problem arises principally because the substrate to be reclaimed is almost always derived from mining or earth moving, and it is largely undeveloped subsoil or rock or it is polluted. The nature of reclaimed sites necessitates the use of species which are tolerant of exposure and undemanding nutritionally, characteristics often associated with pioneer species including alien trees (Savill 1997).

Suitable species for planting on mine spoils should possess the ability to: (1) grow on poor and dry soils; (2) develop the vegetation cover in a short time and to accumulate biomass rapidly; (3) bind soil to arrest soil erosion and check nutrient loss; and (4) improve the soil organic matter status and soil microbial biomass, thereby enhancing the supply of plant nutrients available. In addition, the species should be economically valuable (Singh et al. 2006). Species with exceptional physiological tolerances to improve site conditions and initiate soil-forming processes means that alien species of *Acacia*, *Alnus*, *Betula*, *Eucalyptus*, *Pinus*, *Salix* and other pioneers are frequently employed (Evans 2009a).

Unlike restoration of less severely degraded land, the use of alien tree species remains an acceptable option for mineland revegetation (D’Antonio & Meyerson 2002; Li 2006) if they fulfil a temporary successional role to colonise and ameliorate severely degraded sites and facilitate colonisation and eventual dominance by native flora (Seo et al. 2008).

4.2.7 Alien trees in Short-Rotation Forestry, Short-Rotation Coppice

Two main drivers have pushed renewable energy production to the top of global agendas: climate change and energy security. Fast-growing poplars and willows can be cultivated in short-rotation forestry (SRF) cycles of 15–18 years, but in short-rotation coppice (SRC) this is reduced further by cut-back/coppicing at 3–5-year intervals (Karp & Shield 2008).

It has been suggested that short-rotation forestry has the potential to deliver greater volumes of biomass from the same land area than alternative biomass crops. Short-rotation forestry is the practice of cultivating fast-growing trees that reach their economically optimum size between eight and 20 years old; each plant produces a single stem that is harvested at around 15 cm diameter. The crops tend to be grown on lower-grade agricultural land, previously forested land or reclaimed land and so do not directly compete with food crops for the most productive agricultural land (McKay 2011).

Of the 330–500 species of willow, the shrub willows (*Salix viminalis* in Europe and *Salix eriocephala* in North America and Canada) are deemed most suitable as bioenergy crops (Kuzovkina et al. 2008). Other species used include *S. dasyclados*, *S. schwerinii*, *S. triandra*, *S. caprea*, *S. daphnoides* and *S. purpurea*, and many varieties are interspecific hybrids. Compared with willows, there are relatively few poplar species that fall into six morphologically and ecologically distinct sections. Of these, *Aigeiros* (cottonwoods, *Populus nigra*) and *Populus alba* (aspens, white poplars) are of most relevance for bioenergy (Karp & Shield 2008). Many other alien species (including hybrids and genetically modified trees) are used or tested for SRF/SRC, e.g., *Acacia angustissima*, *Gliricidia sepium* and *Leucaena collinsii* in Zambia (Kaonga 2010), *Eucalyptus* spp. and hybrids (e.g., *Eucalyptus grandis* × *E. urophylla* and freeze-tolerant *Eucalyptus* clones), *Platanus occidentalis*, *Pinus taeda*, *Liquidambar styraciflua* in the USA (Hinchee et al. 2009), *Robinia pseudoacacia* in Albania, Italy, Germany, Hungary and Spain (Grünewald et al. 2009; González-García et al. 2011; Rédei et al. 2011a; Kellezi et al. 2012; Ciccarese et al. 2014), *Acacia saligna* in Israel (Eggleton et al. 2007), *Eucalyptus* spp. in UK[78] (Evans 1980; Leslie et al. 2012) and in China[79] (Wu et al. 2014), *Acacia* hybrid (*Acacia mangium* × *Acacia auriculiformis*) in Vietnam (Kim et al. 2011), to mention a few.

At the regional scale, significant uncertainties exist and there is a major concern that extensive commercial production with non-native trees could have negative effects on biodiversity, in particular in areas of high nature-conservation value. However, integration of biomass species into agricultural landscapes could stimulate rural economy, thus counteracting to some extent negative impacts of farm abandonment or supporting restoration of degraded land, resulting in improved biodiversity values (Dauber et al. 2010; Bianco et al. 2014).

In Austria[80] 10 principles for short-rotation forestry systems, from the viewpoint of nature protection and environment, have been declared since 1998 (Trinkaus 1998). Principle 2 states that "*indigenous* plants should play an important part, because non-indigenous plants (e.g,. *Robinia pseudoacacia* and *Ailanthus altissima*) often show an undesirable tendency to spread".

4.2.8 Alien trees in agroforestry

Agroforestry systems include both traditional and modern land-use systems where trees are managed together with crops and/or animal production systems in agricultural settings. Agroforestry is practiced in both tropical and temperate regions, for both wood and non-wood products, including food and fibre for improved food and nutritional security (Jama & Zeila 2005). The potential of agroforestry to contribute to sustainable development has been recognised in international policies, including the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD), justifying increased investment in its development (FAO 2013). Agroforestry (or "silvoarable

[78] The UK has a climate that is not well suited to the majority of eucalypts. However, there is a small number of eucalypt species that can withstand the stresses caused by frozen ground and desiccating winds or sub-zero temperatures that can occur. These species are from more southern latitudes and high altitude areas of Australia such as, e.g., *Eucalyptuus gunnii* (Leslie et al. 2012).

[79] *E. dunnii, E. grandis, E. grandis × E. camaldulensis, E. urophylla × E. camaldulensis, E. urophylla × E. tereticornis, E. grandis × E. tereticornis, E. urophylla × E. grandis*.

[80] The work was done by an interdisciplinary Austrian team of scientists (phytosociologists, landscape ecologists, experts on forestry, on nature protection and on area planning), which was charged with the responsibility by the Austrian Ministry for Science, Transport and Art.

agroforestry") has traditionally formed important elements of European and Mediterranean landscapes, has the potential to contribute towards sustainable agriculture in Europe in the future, and it is supported by the Common Agricultural Policy (Eichhorn et al. 2006).

Nevertheless, many agroforestry systems, particularly those that depend on tree planting in or near treeless landscapes, rely heavily on alien tree species[81]. As is the case in all endeavours based largely on non-native species, problems arise when these alien trees spread from sites of introduction and cultivation to invade areas where their presence is, for various reasons, deemed inappropriate. In some areas, problems caused by the spread of invasive alien agroforestry trees from sites set aside for this land use pose a serious threat to biodiversity that may reduce or negate any biodiversity benefit of the agroforestry enterprise (Richardson et al. 2004).

4.2.9 Alien trees in Mediterranean planted forests and sand dune stabilisation

Planted forests in the Mediterranean have a long history. In mountainous areas, planted forests with introduced coniferous trees were once limited to land at risk from erosion, but these now cover large areas of pastoral land and even agricultural land, either as a result of the naturalisation and establishment of the introduced species (e.g., *Pinus nigra*) or through colonisation of abandoned land. *Pinus radiata* was planted in more than 300,000 ha in old fields, in Spain during the second half of the 20th century, mainly in Atlantic areas. More recently, the species has also been planted in acid soils of the wet Mediterranean area in former agricultural lands restricted to areas with lime-free soils and annual rainfall exceeding 700 mm (Romanyà & Vallejo 2004). In coastal areas, planted forests dominated by pines (*Pinus halepensis*, *P. pinaster*, *P. pinea*) are very common[82] and are increasing in extent, despite an increase in major forest fires. Traditional forest activities (e.g., cork extraction, *P. pinaster* sawmills) have been replaced by multiple uses linked to tourism, hunting, and recreational activities (Etienne 2000).

In Turkey, afforestation with *P. pinaster* was undertaken by the French for the protection of sand dunes around Terkos Lake in 1880 (Deniz & Yildirim 2014). The first substantial plantings of forest trees in Israel were carried out by the Jewish settlers of Hadera in 1890. They planted *Eucalyptus* species (mainly *E. camaldulensis*) in an attempt to dry up the nearby swamps and for sand dune stabilisation (Bonneh 2000).

Italian foresters developed successful techniques for stabilising sand dunes, and as a result of their efforts several thousand hectares of dunes were fixed and afforested in Italy and in Libya in the '40s with *Pinus* spp., *Acacia* spp. and *Eucalyptus* spp. In Libya, beneficial effects were obtained, particularly from the standpoint of protection of highways. Before the Italian Forest Service started its work, the roads from Tripoli to Homs (Lebda) and into the interior were considered unsafe and necessitated many detours (Messines 1952).

BOX 4.2.9.1: Colonisation of Pinus halepensis in Mediterranean habitats: consequences of afforestation, grazing and fire.

Native populations of *Pinus halepensis* in Israel are restricted to the Carmel region and several other mountainous locations. This species was extensively used for afforestation in Israel during the 20th century, and it now constitutes as much as 30% of the planted forests that cover about 100,000 ha within Israel's Mediterranean zone. These forests were planted in a variety of habitat types, some of which are

[81] For example, in NW Italy as reported by Sitzia et al. (2013).

[82] *Cf.* http://www.magrama.gob.es/es/costas/temas/proteccion-costa/conociendo-litoral/documentacion/especies-invasoras.aspx. See also European Commission (2013), Manual of European Union Habitats and the Council Directive 92/43/EEC, of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (2270* Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*; 9540 Mediterranean pine forests with endemic Mesogean pines).

clearly beyond the natural distribution of *P. halepensis* as currently recognised (Liphschitz & Biger 2001). The seed sources that were used for these plantations were mostly alien, and genetically different from the local eastern Mediterranean ecotype (Schiller & Grunwald 1987). There is widespread expansion of *P. halepensis* from plantations into adjacent natural sites, some of which are of high conservation importance (Lavi et al. 2005). This has become an important environmental issue and a topic of ongoing debate among foresters and conservationists. It is clear that the pine expansion is related to the extensive use of *P. halepensis* for afforestation, but the factors that determine the intensity and dynamics of this process are poorly understood (Richardson & Bond 1991; Osem et al. 2011).

4.2.10 Alien trees in arid zones: preventing and combating desertification

Desertification affects millions of the most vulnerable people in Africa, where two thirds of the land cover consists of drylands and deserts. Desertification refers to land degradation in arid, semi-arid and sub-humid areas resulting from factors such as human pressure on fragile eco-systems, deforestation and climate change. Desertification and land degradation have a strong negative impact on the food security and livelihoods of the local communities in Africa's drylands, home to the world's poorest populations (FAO 2014).

Sand encroachment[83], which has devastating environmental and socio-economic impacts, is another desertification challenge. It reduces arable and grazing land, and diminishes the availability of water resources, threatening the productivity of ecosystems (FAO 2010a).

The Great Green Wall initiative is a pan-African proposal to "green" the continent from west to east in order to battle desertification. It aims at tackling poverty and the degradation of soils in the Sahel-Saharan region, focusing on a strip of land of 15 km wide and 7,100 km long from Dakar to Djibouti (Dia & Duponnois 2010). The project has faced opposition, despite its stated commitment to combating drought and desertification, and in some case criticised as poorly conceived in terms of both ecological and socio-economic considerations. *Prosopis juliflora*[84] is one the species planned to be planted (Dia & Duponnois 2010).

A "Great Green Wall" designed to stop rapidly encroaching deserts and combat climate change is under construction across China. It is a 4,480-km belt of forest across 551 counties and 13 provinces in north-west, central north and north-east China. Part of broader national environment programmes, it is the world's largest ecological development, and is designed to halt 2,460 km^2 of land being lost annually to the expanding Gobi Desert due to overgrazing, deforestation and drought. By 2050, the artificial forest is to stretch 400 million ha – covering more than 42 % of China's landmass. The project began in 1978, and three years later the National People's Congress, China's top legislative body, passed a resolution to make it the duty of every citizen above age 11 to plant at least three poplar, eucalypt, larch or other saplings every year (Levin 2005).

[83] Sand encroachment is said to take place when grains of sand are carried by winds and collect on the coast, along water courses and on cultivated or uncultivated land. As the accumulations of sand (dunes) move, they bury villages, roads, oases, crops, market gardens, irrigation channels and dams, thus causing major material and socioeconomic damage. Desertification control programmes must then be implemented in order to counter this very serious situation (FAO 2010b).

[84] Among the 44 recognized *Prosopis* species, *P. glandulosa*, *P. velutina*, *P. juliflora*, and *P. pallida* are considered the most invasive. In Africa, Prosopis species are estimated to have invaded over four million ha, threatening crop and range production, desiccating limited water resources, and displacing native flora and fauna (Mwangi & Swallow 2005; Shackleton et al. 2014; Wakie et al. 2014; Shackleton et al. 2015).

4.2.11 Genetically improved and genetically modified alien trees

Diverse biotechnological methods are being intensively pursued to support planted forest with alien trees. These include clonal propagation[85], interspecific hybridisation, the use of a variety of molecular tools to intensify the selection of superior genotypes (DNA fingerprinting, genome mapping, gene identification and genome sequencing) and transformation (Grattapaglia & Kirst 2008; Strauss et al. 2009). However, of this diverse array of technologies, only transformation, defined by the use of direct modification and asexual insertion of DNA into organisms in the laboratory (that is, genetic engineering or modification), engenders attention from the CBD[86], strong government regulation and controversy over its use, even for research (Strauss et al. 2009).

The goals for genetically modified (GM) tree forestry are highly diverse, as are the locations, the species and the genes employed. Besides the use of genes from other species, genetic modification can involve changes of the expression of native genes to modify endogenous traits, such as wood structure, growth rate and tolerance of stress. Such activities have been increasing as knowledge of the genomes of trees increases, and genetic modification as a means to leverage genomic information is viewed as particularly important for trees versus annual crops because of the slow pace of tree breeding and the limited state of tree domestication (Strauss et al. 2009).

Traits introduced to GM trees include modification (quality and quantity) of lignin and cellulose composition, optimised biomass for biofuel production, resistance to pests and diseases, herbicide tolerance, altered growth and reproductive development, among others. Hence, GM technology is expected to be part of the toolbox for the future breeding of trees for agriculture and forestry use (Aguilera et al. 2013). Commercial potential has been demonstrated in the field for a few traits, in particular herbicide tolerance, insect resistance, and altered lignin content. Now that commercial implementation has become feasible[87], at least for the few genotypes that can be efficiently transformed and propagated, environmental concerns have become the main obstacle to public acceptance and regulatory approval (Strauss et al. 2009). Ecological risks associated with commercial release range from transgene escape and introgression into wild gene pools to the impact of transgene products on other organisms and ecosystem processes. Evaluation of those risks is confounded by the long life span of trees, and by limitations of extrapolating results from small-scale studies to larger-scale planted forests (Frankenhuyzen & Beardmore 2004).

Many tree species are the focus of GM research. Frankenhuyzen and Beardmore (2004) identified 33 species of forest trees that had been successfully transformed and regenerated. Although most field trials have occurred in poplar because of its status as a model organism for tree genomics and biotech (e.g., Jansson & Douglas 2007), and most have occurred in the United States, field tests have also been conducted in a number of other tree species and geographies around the world. Plantation trees predominate, with poplar leading, followed by pine and eucalypts (Strauss et al. 2009).

One of the key issues concerning such introductions is the introgression of novel genome regions (including alien genes, transgenes, or any type of heritable genomics-derived modification) into natural

[85] E.g., Rédei et al. (2002, 2011a, b).

[86] At its 8th Conference of the Parties (COP8) 20 - 31 March 2006 - Curitiba, Brazil, the Convention on Biological Diversity adopted the Decision VIII/19 “Forest biological diversity: implementation of the programme of work” recommending “Parties to take a precautionary approach when addressing the issue of genetically modified tree”. This Decision recognized “the uncertainties related to the potential environmental and socio-economic impacts, including long-term and transboundary impacts, of genetically modified trees on global forest biological diversity, as well as on the livelihoods of indigenous and local communities, and given the absence of reliable data and of capacity in some countries to undertake risk assessments and to evaluate those potential impacts”. See also COP 9 Decision IX/5 on “Forest biodiversity” 19 - 30 May 2008 - Bonn, Germany, and the EU Directive 2001/18/EC (Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms and repealing Council Directive 90/220/EEC - Commission Declaration, Official Journal L 106, 17/04/2001 P. 0001 – 0039).

[87] *Cf.*, Ledford (2014).

populations of wild species. Monitoring the rate of introgression between native and alien poplar species has recently been the focus of a large research effort (e.g., Fossati et al. 2003; Smulders et al. 2008). However, the occurrence of introgression depends on many factors, including the interfertility of the species, the actual occurrence of hybridisation, the fitness and fertility of the hybrids produced, and the degree of backcrossing (Meirmans et al. 2010). Additionally, Di Fazio et al. (2012) have shown that levels of transgene spread are strongly affected by ecological and management factors that affect habitat creation and the abundance of mature transgenic trees on the landscape.

Research on the strategies and risks of introducing plants with novel traits into natural populations is still in its infancy. Trees are much longer lived and have much longer generation times than annual crops, which makes research more lengthy and difficult. Given the high rates of gene flow found between poplar planted forests and natural populations (Vanden Broeck et al. 2005; Di Fazio et al. 2012), tools for mitigating gene flow should be developed if the introduction of the novel trait is deemed to pose a risk.

Given the diversity of traits, species and environments, a case-by-case approach would seem to be the sensible way to proceed, and this basic approach is officially recognised in the Cartagena Protocol. Annex III/6, under general principles governing risk assessment, states that "risk assessment should be carried out on a case-by-case basis (see also FAO 2010c). The required information may vary in nature and level of detail from case to case, depending on the living modified organism concerned, its intended use and the likely potential receiving environment." This principle fits well with the diversity of GM trees (Strauss et al. 2009).

There is also scope for deploying genetically engineered sterile alien trees to reduce problems of invasiveness through reduced seed production, but one obstacle to this solution is that FSC regulations expressly forbid any use of GM trees (Strauss et al. 2004; Brunner et al. 2007; Meirmans et al. 2010; Richardson 2011). In addition, some alien tree species (*Ailanthus altissima*, *Populus* spp., *Robinia pseudoacacia*) spread very efficiently also by vegetative propagation.

4.3 The negative impacts of invasive alien trees

4.3.1 Generalities and key examples

According to FAO (2012), invasive alien tree species are species that are non-native to a particular ecosystem and whose introduction and spread cause, or are likely to cause, socio-cultural, economic or environmental harm or harm to human health.

In accordance with the CBD definition, "invasive alien species" means an alien species whose introduction and/or spread threaten biological diversity (Decision V/8 of the Conference of the Parties to the Convention on Biological Diversity). According to art. 3 of the Regulation (EU) No. 1143/2014, "invasive alien species" means an alien species whose introduction or spread has been found to threaten or adversely impact upon biodiversity and related ecosystem services (*Cf*. Section 1 of this Code).

Alien trees planted for production or for other purposes have strong direct positive economic impacts on the local and national economies of many countries, but often lead to sharp conflicts of interest when the alien species become invasive, and to negative impacts on the ecosystem (Dodet & Collet 2012; van Wilgen & Richardson 2012; Dickie et al. 2014).

In many parts of the world, some naturalised alien trees now feature prominently on the lists of invasive alien plants, and in some areas, alien tree species are now among the most conspicuous, damaging and, in some cases, best-studied invasive alien species. Twenty-one woody plant species feature on the widely cited list of "100 of the World's Worst Invaders" (Lowe et al. 2000), seven woody plants appear on a list of "100 of the worst" invasive species in Europe[88] (Richardson & Rejmánek 2011), and many trees and shrubs are black-listed in Europe (see Annex 6.2).

Different types of planted forests have provided very important pathways for the introduction and dissemination of (invasive) alien trees (Wilson et al. 2009; Richardson & Rejmánek 2011; Donaldson et

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[88] http://www.europe-aliens.org/speciesTheWorst.do .

al. 2014). In most cases, alien trees are selected for their adaptability to many habitats, including harsh sites, as well as rapid growth – both features that are shared with invasive alien species (Richardson 1998b).

Evidence has accumulated rapidly around the world on the factors that contribute to invasions of alien trees used in different forms of forestry in the past few decades (Richardson et al. 2014). Importantly, insights on the drivers of such invasions have been shown to be, to some extent and with due care, transferable between regions – regions with recent plantings can learn important lessons from environmentally similar regions in other parts of the world with longer histories of planted forests (Richardson et al. 2015).

Partly because of their large size, but also for other reasons, many alien trees are important ecosystem engineers. Alien tree invasions are among the most costly to manage because trees generally produce high biomass and they impact on ecosystem services such as water provision where they invade grasslands and shrublands (Richardson 1998a; Le Maitre et al. 2002; van Wilgen & Richardson 2012; Richardson et al. 2014). Many invasive alien tree species cause regime shifts in invaded ecosystems, leading to impacts that ripple across trophic levels (Gaertner et al. 2014).

Alien tree invasions are currently more widespread outside Europe (especially in the southern hemisphere). For this reason, in this Code, many insights are drawn from other regions where appropriate to sketch scenarios and develop principles that are needed to define a code of conduct for Europe and the Mediterranean. In many cases, such insights relate directly to species that are also commonly planted in Europe.

Invasive alien trees can simultaneously bring benefits and cause substantial environmental harm, very often leading to conflicts over how they should be managed. The impacts grow over time as invasions spread, and societal perceptions of the value of (invasive) alien trees also change as understanding grows and as values shift (Dickie et al. 2014; van Wilgen & Richardson 2014).

The benefits and impacts of invasive alien trees vary in their type and magnitude, depending on the species, their invasive potential, the extent to which they have invaded, and the nature of the invaded environment. The magnitude of benefits and of impacts can be viewed as separate, independent continua, which allows for the classification of species into four broad types (Fig. 1).

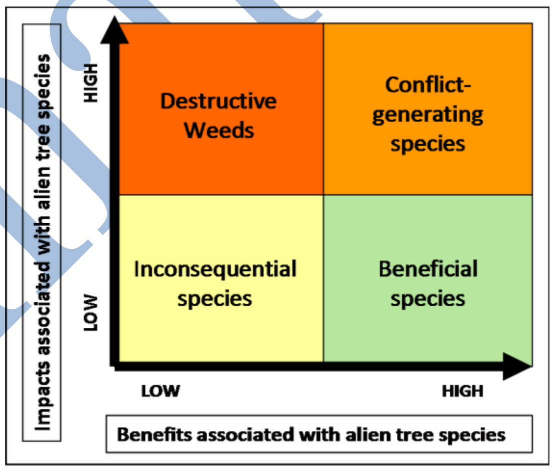

Fig. 1 – Types of invasive alien trees based on their relative degree of impact on the environment and the benefits associated with their cultivation and utilisation. Redrawn from van Wilgen & Richardson (2014). The position of any alien tree species within this framework is dynamic.

According to the categorisation proposed by van Wilgen & Richardson (2014), many alien tree species are not invasive, and are either inconsequential, as they have neither substantial impacts nor benefits, or beneficial in cases where they produce useful products, such as wood or fruit, or provide useful ecosystem services, such as sand stabilisation or erosion control. It is important to note that the position of any alien tree species within this framework is dynamic. Crucial factors in this regard are the residence time and introduction effort (propagule pressure), but management interventions and changing socio-political conditions can also determine the position of species in this categorisation scheme. A few invasive alien tree species provide very little in the way of benefits. Such trees are easily classified as “destructive weeds”, and there is little disagreement about attempts to eradicate or contain such species. Because of the wide variety of uses of trees for humans, there are very few species that can be placed unequivocally in this category. The final type includes species that are both useful and invasive - it is these species that generate controversy and conflict. Finding sustainable solutions to their management is a considerable and escalating problem. Prominent examples include species in the genera *Acacia*, *Casuarina*, *Eucalyptus*, *Pinus*, *Pseudotsuga*, *Populus*, *Prosopis* (Wise et al. 2012; Shackleton et al. 2014) and *Salix* (van Wilgen & Richardson 2014).

The number of species falling into this category is increasing rapidly, since the initial benefits of many alien tree species become negated by the impacts when the species become invasive. With an increase in the area planted, the number of species planted and the time since introduction, the number of conflict situations is escalating (van Wilgen & Richardson 2014).

The many benefits of alien trees that are both useful and invasive include: timber production, aesthetic value and appeal, rehabilitation of degraded land, water protection, erosion control and mitigation of sand storms and sand-drift, food for humans, fodder for livestock, carbon sequestration, agroforestry, energy, biodiversity conservation (van Wilgen & Richardson 2014), facilitation of indigenous tree species regeneration, recreation and landscape amenity. Responsible management of planted forests has a critical benefit to natural forest ecosystems as it reduces the pressures on indigenous forest for forest products and allows them to be designated for other protective and conservation purposes (FAO 2010c; Mead 2013).

The role of planted forests of alien tress in biodiversity conservation is now better understood (Brockerhoff et al. 2008). For example, in the fragmented forest landscape of Europe, planted forests comprise an increasingly important fraction of the matrix surrounding natural forest fragments. Planted forests may provide habitat for forest biodiversity, which may enhance landscape connectivity and regional biodiversity (Bremer & Farley 2010).

Quine and Humphrey (2009) compared the species richness of a range of different taxonomic groups (lichens, bryophytes, fungi, vascular plants, invertebrates and songbirds) in alien and native forest stands of differing structural stages in northern and southern Britain. In terms of overall native species-richness no significant difference between the alien and the native stands was detected, but lichen species richness was much lower in the alien stands compared to the native stands, whereas bryophyte and fungal species richness was proportionately higher in the alien stands. They concluded that emergent ecosystems of alien conifer species are not irrelevant to biodiversity. Where already well-established they can provide habitat for native species particularly if native woodland is scarce and biodiversity restoration is an immediate priority (Quine & Humphrey 2009).

On the contrary, Calviño-Cancela (2013) described a paucity of birds in planted forests of *Eucalyptus globulus* in Galicia, Spain, compared with the diverse and abundant avifauna in planted forests of pines. The alien status and taxonomic isolation of *E. globulus* in the region, together with specific features of its leaves and bark, may explain the low suitability of eucalypt planted forests, by limiting the presence of phytophagous insects and thus the availability of prey for birds (Calviño-Cancela 2013).

Invasive alien trees escaping from planted forests may affect invaded ecosystems and ecosystem functioning and services in many ways. Many act as **transformers** (ecosystem engineers), i.e. they are invasive alien trees that reach very high densities and substantially increase biomass or change the type and arrangement of above-ground material. In some cases, the impacts of tree invasions are obvious, fast and dramatic. Some invasions have radically transformed entire ecosystems.

For example, invasive alien *Acacia* and *Pinus* species have rapidly transformed species-rich fynbos shrublands in South Africa and sand-dune vegetation in Portugal into species-poor, forests or woodlands dominated by alien species and with markedly changed biodiversity and ecosystem functions. Invasion of *Melaleuca quinquenervia* in Florida's Everglades[89] has changed large areas of open grassy marshes to closed-canopy swamp-forests.

The net effect of invasive alien trees is determined by the product of the per-capita effect, the abundance they achieve (reflected by numbers of stems per area, or the total biomass added), and their geographical range (Parker et al. 1999). Some invasive alien trees have no obvious impacts, some have localised impacts, while others cause massive ecosystem-level transformations. Some of the most prominent effects of invasive alien trees in different parts of the world are summarised below, following the impact categories of Richardson et al. (2000). Full details and references for the examples given are provided in Richardson & Rejmánek (2011).

Excessive users of resources: Many invasive alien trees invade riparian ecosystems where they achieve dominance and huge abundance and thus consume more water than would the native species that normally frequent these ecosystems. The impact is due primarily to increased biomass and therefore increased water use. Prominent examples are *Tamarix* spp.[90] in SW North America (Stromberg et al. 2007) and *Acacia* species, notably *A. mearnsii*, in South Africa (Dye & Caren 2004) and in South Sardinia (Italy).

Donors of limiting resources: Many invasive alien species of woody legumes impact invaded ecosystems primarily via their addition of nitrogen. Well-studied examples are *Morella faya* which doubles canopy nitrogen as it replaces native forest species in Hawaii, the Australian *Acacia* species in South Africa and in the Mediterranean, and *R. pseudoacacia* which increases the soil nitrogen pools in nitrogen-poor soils in Europe (e.g., Sitzia et al. 2012; Cierjacks et al. 2103; González-Muñoz et al. 2013). *A. altissima* increases the availability of mineral nitrogen under its canopy due to the large amounts of fast-decomposing litter that it produces (González-Muñoz et al. 2013; Medina-Villar et al. 2015).

Fire promoters/suppressors: The best-studied example of an invasive alien tree that brings fire to a previously fire-free system is that of *Melaleuca quinquenervia* invasions of wetland habitats in Florida, USA, where a massive increase in flammable material leads to very intense fires. Examples of where alien tree and shrub invasions have suppressed fire frequency are *Mimosa pigra* in northern Australia and *Triadica sebifera* and *Schinus terebinthifolius* in North America; in all cases alien tree invasions result in reduced horizontal continuity of fuel which reduces fire frequency and intensity (Brooks et al. 2004).

Sand stabilisers: Australian *Acacia* species have been widely planted along coastal dunes in several parts of the world to stabilise sand movement. Planted and self-sown stands of species like *A. cyclops* perform this function very well; in some areas of South Africa dune stabilisation has resulted in massive beach erosion. In the Portuguese dune ecosystems, *Acacia longifolia* and *A. saligna* are among the most aggressive invasive alien tree species. These alien woody legumes were planted at the beginning of the last century to curb sand erosion but have now proliferated, often associated to fire events, causing significant ecological impacts. Long-term occupation by *A. longifolia* significantly altered the soil properties with increased levels of organic C, total N and exchangeable cations resulting in higher microbial biomass, basal respiration, and b-glucosaminidase activity (Marchante 2001; Marchante et al.

[89] *Melaleuca quinquenervia*, introduced to Florida in the late 1800s as an ornamental and for other purposes (drying up wetlands), is now the most prominent of 60 non-native plant species invading many natural wetland and upland areas in Florida, including the Everglades, a United Nations World Heritage site and UNESCO Man and Biosphere Reserve. *Malaleuca* invasion has determined displacement of native species, reduction in wildlife habitat value, alteration in hydrology, modification of soil resources, changes in fire regimes (Mazzotti et al. 2014).
[90] Tamarisk taxa (*Tamarix ramosissima*, *T. chinensis* and their hybrids) were introduced to the United States from Asia in the late 1800s for the control of soil erosion and landscaping purposes. They are now the third most prevalent alien tree riparian taxon in the western United States (Friedman et al. 2005).

2003; Marchante et al. 2008). The replacement of drought tolerant native species by the water spending invader, *A. longifolia*, may have serious implications for ecosystem functioning, especially during the prolonged drought periods predicted to occur in Portugal in the future (Rascher et al. 2011).

Colonisers of intertidal mudflats/sediment stabilisers: Red mangrove (*Rhizophora mangle*) was introduced to Hawai'i in 1902 to control runoff from upstream agriculture. Other species of alien mangrove have been introduced to Hawai'i, but *R. mangle* is the most successful, occupying coastal habitats throughout the main Hawaiian Islands, including estuarine fishpond sites developed for aquaculture by native Hawaiians as early as 1000 C.E. (Siple & Donahue 2013).

In their native range, mangroves are ecosystem engineers, strongly modifying their environment and providing important ecosystem services, including shoreline protection, entrapment of heavy metals, sediment stabilisation, litterfall subsidy, and nursery grounds (Siple & Donahue 2013). In their introduced range, these potential ecosystem services must be weighed against impacts on native ecosystems: In Hawai'i, alien mangroves create habitats dramatically distinct from the sandflats inhabited by the few native coastal macrophytes, transforming nearshore sandy habitat into heavily vegetated areas with low water velocity, high sedimentation rates, and anoxic sediments. Alien mangrove forests provide habitat for alien species, including burrowing predators, which can exert top-down effects on benthic communities (Siple & Donahue 2013).

Litter accumulators: The North American *Pinus strobus* invades both natural *P. sylvestris* forests and planted forests of the latter species in sandstone areas of the Czech Republic. *Pinus strobus* produces greater quantities of more slowly decomposing litter than its native congener which has a major effect on soil acidity. Under such conditions, *P. strobus* regenerates better than *P. sylvestris* which contributes to its success as an alien invader (Pyšek & Prach 2003). In Central Europe, many sandstone areas are protected for their unique environment, and large-scale regeneration of this invasive alien tree species is of concern (Hadincová et al. 2007; Mandák et al. 2013).

Invasive alien tree species can **hybridise and introgress** if the species have taxonomical close relatives in the native flora. This can be undesirable from a conservation point of view (Rhymer & Simberloff 1996; Smulders et al. 2008; Felton et al. 2013; Kjær et al. 2014), especially if the native species are rare[91] in number compared to planted individuals of the invasive alien tree.

Many invasive alien trees qualify as "**transformers**" sensu Richardson et al. (2000). Well-studied examples of are Australian *Acacia* species (in Chile, Portugal, South Africa), *Cinchona pubescens* (Galapagos islands), *Ligustrum robustum* var. *walkeri* (La Réunion Island), *Melaleuca quinquenervia* (Florida, USA), *Miconia calvesens* (Tahiti), *Mimosa pigra* (northern Australia & Zambia), *Morella faya* (Hawaii), *Pinus pinaster* (South Africa), and *Triadica sebifera* (North America).

Besides the effects mentioned above that are attributable to effects on physical resources either due to large size and biomass or impacts on resource availability, many alien tree and shrub invasions affect resident biota in more subtle ways. An important category of impacts for invasive alien tree species is the alteration of habitat for other organisms. A few examples from different parts of the world illustrate the very wide range of changes that invasive alien trees can cause. In Hawaii, the spread of alien mangroves has led to habitat loss for wetland birds (Allen 1998; Siple & Donahue 2013). The new mangrove habitats also provide refugia for shorebird predators, including invasive rats (*Rattus* spp.) and mongooses (*Herpestes* spp.), and alien marine species such as the mangrove crab (*Scylla serrata*). Emergent roots of invasive *Rhizophora mangle* are also colonised by various introduced barnacles and sponges, thus altering the structure of macrofaunal communities. Many invasive alien trees have a major impact by creating impenetrable thorny thickets that limit the passage of animals (e.g., *Caesalpinia decapetala*, *Mimosa*

[91] E.g. *Abies nebrodensis*, or Sicilian fir, is an endemic species of Sicily, Italy, growing on the Madonie range at 1700–1900 m above sea level. It is a highly endangered species (Council of Europe 1977), comprising a single relict population of approximately 30 adult trees spread over an area of 150 ha (Ducci 2014).

pigra, and *Prosopis* spp.). *Annona glabra* invades Australian estuaries and chokes mangrove swamps, where its seedlings carpet the banks and prevent other species from germinating or surviving. Invasion of these riparian zones by willows (*Salix* species) decreased food resources and altered habitat, reducing native bird diversity and disrupting connectivity of the riparian zone. On the island of Sao Miguel in the Azores archipelago, invasion of the native forest by the alien tree *Pittosporum undulatum* and other alien species led to a marked reduction in structural complexity and an impoverished flora. This led to a reduction in insect biomass, due to the replacement of large insects on native plants with small insects on alien plants. This appears to have far-reaching negative consequences for ecosystem stability (Heleno et al. 2009).

Besides the diverse ecological effects discussed above (many of which are associated with modification of ecosystems), alien tree invasions have many complex effects on human livelihoods, both positive and negative. These have been clearly documented in South Africa (especially for Australian acacias) and Papua New Guinea (due to invasion of *Piper aduncum*). *Prosopis* invasions in sub-Saharan Africa have led to considerable rangeland degradation, causing many problems for human societies, especially those relying on subsistence agriculture (e.g., Mwangi & Swallow 2005; Shackleton et al. 2014). Alien tree invasions have huge financial costs in many regions.

In Britain several alien trees have become culturally naturalised (Mabey 1996; Peterken 2001) causing a change in the perception of nature. *F. sylvatica* in northern and western Britain is widely accepted by the general public as a native. *A. pseudoplatanus* is regarded as traditional by remote farm buildings in Wales and northern England. *P. sylvestris* is seen as a natural part of the scenery in southern heathlands (Peterken 2001).

Alien tree invasions into grasslands and shrublands convert many unique vegetation formations into virtual monocultures of alien trees. Macdonald et al. (1988) recognised the analogy between invasion of *Cinchona pubescens* into shrubby highland communities of the Santa Cruz Island, Galapagos, and invasion of alien pines and acacias into fynbos shrublands in South Africa. These alien tree invasions are key contributors to the degradation of such ecosystems over much of their extent.

Picea sitchensis originates from the west coast of North America and is imported to Norway mainly as a production species for planted forests, although it is also used for shelter belts. Historically, the species has also been imported for research purposes, but such importations have now ceased. *Picea sitchensis* has been established in Norway since the '50s and is the most important alien tree species in terms of extent of planting. The species is mainly planted in coastal areas in heaths, grazed blueberry forest and small fern forest. It is considered an invasive alien primarily in these types of habitats where is expected to spread further (Gederaas et al. 2012).

Box 2.5.1.1 Invasive alien Acacia species.

Invasive alien *Acacia* species, like many other invasive alien species, have many types of impacts including some that interact synergistically. Alien *Acacia* species can induce simultaneous changes in the above- and below-ground communities, microclimates, soil moisture regimes and soil nutrient levels (Marchante et al. 2003, 2008b; Yelenik et al. 2004; Werner et al. 2010; Gaertner et al. 2011). Many changes are directly attributable to key traits of *Acacia* species: their rapid growth rates and ability to out-compete native plants (Morris et al. 2011); their capacity to accumulate high biomass; large, persistent seed banks; and their capacity to fix nitrogen (Yelenik et al. 2007). These features enable them to dominate competitive interactions with native species. Many of the abiotic changes and biotic responses to them are tightly linked and may advance simultaneously rather than sequentially (Hobbs et al. 2009), as does the progression from structural to functional impacts (Le Maitre et al. 2011). The impacts of invasive alien Australian acacias on biodiversity and ecosystem properties and functions also affect the delivery of ecosystem services and the benefits that society derives from them. Affected ecosystem services include: supporting services (e.g. soil formation); regulatory services (e.g. water flow and nutrient cycling);

production services (e.g. food and fibre); and cultural or life-enhancing services (e.g. recreation or educational opportunities to sustain human well-being) (Le Maitre et al. 2011).

Finally, past experience of introducing tree species from other countries shows that one of the possible negative outcomes could be the failure of the introduced tree to grow successfully (Engelmark et al. 2001). Alien tree species are widely used in planted forests for their supposed high productivity and performance compared to native trees. However, these advantages may be compromised by herbivore damage, insects and microbial pathogens, which are introduced accidentally and/or have adapted to new host trees (Branco et al. 2014; Wingfield et al. 2015).

4.4 International initiatives and legislation on invasive alien species and invasive alien trees

Many international instruments refer to invasive alien species that may have undesired environmental or economic impacts. These range from legally binding treaties to non-binding technical guidance focused on particular species or pathways. The main international regulations concerning invasive alien species are given in the following with specific reference to invasive alien trees and planted forests. The information here provided is intended to provide support to the principle 4.1.1 of the present Code.

4.4.1 The Convention on Biological Diversity

The Convention on Biological Diversity (CBD), negotiated under the auspices of the United Nations Environment Programme (UNEP), was adopted in 1992 and entered into force in 1993. Its aims are the conservation of biological diversity, the sustainable use of biological resources, and the fair and equitable sharing of benefits arising from the use of genetic resources (Secretariat of the Convention on Biological Diversity 2001a, 2001b). CBD requires Parties "as far as possible and as appropriate (to) prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species" under the provision of Article 8(h).

Given this mandate, the Convention's member governments who together constitute the Conference of the Parties (COP) to the Convention made numerous decisions with respect to alien species, many of which are directly relevant to the management of (invasive) alien tree species. In particular, the COP 11 Decision XI/19[92] states that "when designing, implementing and monitoring afforestation, reforestation and forest restoration activities for climate change mitigation, consider conservation of biodiversity and ecosystem services through, for example: (i) Converting only land of low biodiversity value or ecosystems largely composed of non-native species, and preferably degraded ecosystems; (ii) Prioritising, whenever feasible, local and acclimated native tree species when selecting species for planting; (iii) Avoiding invasive alien species; (iv) Preventing net reduction of carbon stocks in all organic carbon pools; (v) Strategically locating afforestation activities within the landscape to enhance connectivity and increase the provision of ecosystem services within forest areas".

[92] COP 11 Decision XI/19, Hyderabad, India, 8-19 October 2012 - "Biodiversity and climate change related issues: advice on the application of relevant safeguards for biodiversity with regard to policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries". *Cf.* also Secretariat of the Convention on Biological Diversity (2002) (https://www.cbd.int/doc/publications/cbd-ts-07.pdf). The section on "unsustainable forest management" reports case studies on *Leucaena leucocephala, Miconia calvescens, Spathodea campanulata* and *Cordia alliodora* impacts.

4.4.2 The Council of Europe and the Bern Convention

The Council of Europe[93] promotes actions to avoid the intentional introduction and spread of alien species, to prevent accidental introductions and to build an information system on invasive alien species (IAS). In 1984 the Committee of Ministers of the Council of Europe adopted a recommendation to that effect. Also, the Bern Convention (Convention on the Conservation of European Wildlife and Natural Habitats), the main Council of Europe treaty in the field of biodiversity conservation, requires its Contracting Parties "to strictly control the introduction of non-native species[94]".

In 2003, the Bern Convention adopted the European Strategy on Invasive Alien Species (Genovesi & Shine 2004), aimed at providing precise guidance to European governments on IAS issues. The Strategy identifies European priorities and key actions, promotes awareness and information on IAS, strengthening of national and regional capacities to deal with IAS issues, taking of prevention measures and supports remedial responses such as reducing adverse impacts of IAS, recovering species and natural habitats affected. National strategies have been drafted and implemented by many of the Parties following the priorities set in the European Strategy. Noteworthy, many Recommendations on IAS have been adopted by the Standing Committee since 1997[95].

4.4.3 The International Plant Protection Convention

The International Plant Protection Convention (IPPC), which has existed since the 1950s, aims to prevent the introduction and spread of plant pests. National plant protection services and the governing body of the IPPC, the Interim Commission on Phytosanitary Measures (ICPM), recognised that the aim of the CBD to prevent the introduction of alien species corresponds in large measure to the aim of the IPPC. Since 1999, the ICPM has been actively engaged in clarifying its role in regard to invasive alien species that are plant pests. In 2001, it determined that such species should be considered quarantine pests and should be subjected to measures according to IPPC provisions. The ICPM also decided that IPPC standards should be reviewed to ensure that they adequately address environmental risks of plant pests. In 2003, the ICPM adopted supplements to two of the international standards for phytosanitary measures

[93] The Council of Europe includes 47 member states, 28 of which are members of the European Union. (http://www.coe.int/en/web/portal/home).

[94] In Article 11, paragraph 2.b of the Convention, each Contracting Party undertakes to strictly control the introduction of non-native species.

[95] Recommendation No. 57 (1997) on the Introduction of Organisms belonging to Non-Native Species into the Environment; Recommendation No. 91 (2002) on Invasive Alien Species that threaten biological diversity in Islands and geographically and evolutionary isolated ecosystems; Recommendation No. 77 (1999) on the eradication of non-native terrestrial vertebrates; Recommendation No. 99 (2003) on the European Strategy on Invasive Alien Species, which recommends that Contracting Parties: draw up and implement national strategies on invasive alien species taking into account the European Strategy on Invasive Alien Species. And co-operate, as appropriate, with other Contracting Parties and Observer States in prevention, mitigation and eradication or containment of aliens species; Recommendation No. 134 (2008) of the Standing Committee, adopted on 27 November 2008, on the European Code of Conduct on Horticulture and Invasive Alien Plants; Recommendation No 141 (2009) of the Standing Committee, adopted on 26 November 2009, on potentially invasive alien plants being used as biofuel crops;
Recommendation No. 142 (2009) the Standing Committee, adopted on 26 November 2009, interpreting the CBD definition of invasive alien species to take into account climate change. It recommends Contracting Parties to the Convention and invites Observer States to: "interpret the term "alien species" for the purpose of the implementation of the European Strategy on Invasive Alien Species as not including native species naturally extending their range in response to climate change"; Recommendation No. 160 (2012) of the Standing Committee, adopted on 30 November 2012, on the European Code of Conduct for Botanic Gardens on Invasive Alien Species; Recommendation No. 179 (2015) of the Standing Committee - Strasbourg, 1 December - 4 December 2015, on action to promote and complement the implementation of EU Regulation 1143/2014 on invasive alien species. (http://www.coe.int/en/web/bern-convention/recommendations-on-ias).

(namely Glossary of phytosanitary terms and Pest risk analysis for quarantine pests). These supplements elaborated on environmental considerations. To avoid conflicting developments within the IPPC and the CBD regarding invasive alien species and plant pests (Lopian 2005; Brunel et al. 2009).

4.4.4 The European and Mediterranean Plant Protection Organisation (EPPO)

The European and Mediterranean Plant Protection Organization (EPPO) is an intergovernmental organisation responsible for European cooperation in plant health. Nearly all countries of the European and Mediterranean region are members. EPPO's objectives are to protect plants, to develop international strategies against the introduction and spread of dangerous pests and to promote safe and effective control methods. It is developing a cooperative Europe-wide strategy to protect the EPPO region against invasive alien plants and created in 2002 a Panel on Invasive Alien Species which was charged with identifying invasive plant species that may present a risk to the EPPO region and proposing measures to prevent their introduction and spread and recommendations on ways to eradicate, suppress and contain invasive alien species that have already been introduced (Brunel et al. 2009).

The Panel has established the EPPO List of Invasive Alien Plants which can be considered as a list of priorities. The alien trees *Acacia dealbata*, *Ailanthus altissima* and *Prunus serotina* are listed in the EPPO list of invasive alien plants[96].

EPPO publishes standards and guidelines, the EPPO Bulletin and the EPPO reporting systems, as valuable sources of information on invasive alien species.

During 2016, a three-day workshop was held at the headquarters EPPO, with the purpose of prioritising a list of invasive alien plants for risk assessment under the LIFE[97] funded project 'Mitigating the threat of invasive alien plants in the EU through pest risk analysis to support the EU Regulation 1143/2014' (LIFE15 PRE FR 001) (see, www.IAP-risk.eu). The workshop was comprised of experts from the EPPO Panel on Invasive Alien Plants, the NERC Centre for Ecology and Hydrology and the EPPO Secretariat. A group of alien tree species were identified as having a high priority for a risk assessment, i.e. *Acacia dealbata*, *Cinnamomum camphora*, *Hakea sericea*, *Prosopis juliflora*, *Sapium sebiferum*.

4.4.5 The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

CITES, which primarily addresses trade in endangered species, can prevent or better regulate the transfer of endangered species that may be invasive alien. It has three different levels of protection for species, reported as Appendices[98]. Although there are literally thousands of plant species protected under

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[96] The plants listed have been identified by the EPPO Panel as being absent or present in the EPPO region; as having a high potential for spread; as posing an important threat to plant health and/or the environment and biodiversity; and eventually as having other detrimental social impacts in the EPPO region. Because a large number of invasive alien plants are already present in the EPPO region, priorities were set in order to select those species considered to pose the greatest threat to species and ecosystems in the EPPO region. EPPO therefore strongly recommends countries endangered by these species to take measures to prevent their introduction and spread, or to manage unwanted populations (for example with publicity, restrictions on sale and planting, and control measures). This List is constantly being reviewed by the Panel (new species can be added and others removed). The list is not meant to be exhaustive but to focus on the main risks (http://www.eppo.int/INVASIVE_PLANTS/ias_lists.htm) .

[97] LIFE is the EU's financial instrument supporting environmental, nature conservation and climate action projects throughout the EU (http://ec.europa.eu/environment/life/).

[98] Appendix I: This appendix represents species that are in the most danger and are considered to be threatened with extinction, and are consequently the most restricted in international trade. Appendix II: This appendix contains species that are at risk in the wild, but not necessarily threatened with extinction. Species in this appendix are closely regulated, but are typically not as restricted as Appendix I. Appendix III: This appendix contains species that a certain country (called a "party" within CITES), has voluntarily requested to be regulated in order to help preserve the species in question. Appendix III species regulation is only applicable for the specific party that has requested its inclusion, and is therefore much less restrictive than Appendix I or II. CITES is implemented in the EU through the

CITES, only a portion of these species are trees, and of the included tree species, only a relatively small portion of them are actually used as lumber. *Araucaria araucana*[99] and *Dalbergia nigra*[100] are included in Appendix I.

4.4.6 Sustainable forest management and forest certification

The idea of having international common guidelines in the forest sector dates back to 1992. The Forest Principles is the informal name given to the "Non-Legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forests", a document produced at the United Nations Conference on Environment and Development (UNCED), informally known as the Earth Summit. It is a non-legally binding document that makes several recommendations for conservation and sustainable development of forestry. Since a statement is, by its nature, non-legally binding, the title's inclusion of these words shows that this non-binding aspect needed extra emphasis, demonstrating the great divergence of views during the UNCED negotiations in 1992 (Ruis 2001). These principles should apply to all types of forests, both natural and planted, in all geographical regions and climatic zones and, importantly, principle 6 (a) states that "all types of forests play an important role in meeting energy requirements through the provision of a renewable source of bio-energy, and that the potential contribution of plantations of both indigenous and introduced species for the provision of both fuel and industrial wood should be recognised".

The FOREST EUROPE process (Ministerial Conferences on the Protection of Forests in Europe, MCPFE), a pan-European voluntary political process for dialogue and cooperation on forest policies in Europe, was started by the Strasbourg Conference in 1990 and the Forest Principles were adopted and incorporated into the agenda by Helsinki Conference in 1993. The concept of sustainable forest management (SFM) was defined as: "The stewardship and use of forest lands in a way and at a rate that maintains their productivity, biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil now and in the future relevant ecological, economic and social functions at local, national and global levels and that does not cause damage to other ecosystems" (European Commission 2016; FOREST EUROPE 2016).

FOREST EUROPE develops common strategies for its 47 signatories (46 European countries and the European Union) on how to protect and sustainably manage their forests. Since 1990, the collaboration of the ministers responsible for forests in Europe has had a great economic, environmental and social impact

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Wildlife Trade Regulations. Currently these are Council Regulation 338/97/EC on the protection of species of wild fauna and flora by regulating trade therein (the Basic Regulation) and Commission Regulation 865/2006/EC laying down detailed rules concerning the implementation of Council Regulation 338/97/EC (the Implementing Regulation). Suspension regulations including 997/2010/EC (5 November 2010) and Regulation 359/2009/EC (30 April 2009) suspend the introduction into the Community of certain species from certain countries.

[99] *Araucaria araucana* has been widely planted as a specimen tree in temperate areas all over the world, but there are virtually no planted forests. A small scale plantation was established in southwest Scotland in 1916 (Williams & Winn 1977; Premoli et al. 2013). Endangered for IUCN, *Araucaria araucana* is listed on Appendix I of CITES which strictly regulates the trade in its timber and seeds (CITES 2014: http://www.iucnredlist.org/details/31355/0).

[100] *Dalbergia nigra* (Vell.) Allemao ex Benth, known as the Brazilian rosewood or jacarandá-da-Bahia, is a tree species endemic to the central Atlantic Forest in Brazil. This species produces a high-quality wood that is highly valued for the manufacture of musical instruments and fine furniture, thus resulting in its overcutting since the colonization of Brazil. *D. nigra* is a threatened tree that is in the "Endangered" category due to its over-exploration, the absence of replacement plantations and the deforestation of the Atlantic Forest - (IUCN). *D. nigra* is extremely rare in nature, and its international trade has been prohibited since the 1990s by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2008, Appendix I, II and III to the Convention on International Trade in Endangered Species of Wild Fauna and Flora. US Fish and Wildlife Service: Washington; Ribeiro et al. 2011; Taylor et al. 2012). Further information can be found in the Resolution Conf. 13.10 (Thirteenth meeting of the Conference of the Parties - http://www.cites.org/eng/res/13/13-10.php).

on the national and international level. FOREST EUROPE has led to achievements such as the guidelines, criteria and indicators for sustainable forest management (FOREST EUROPE 2016).

The first two set of guidelines, "General guidelines for sustainable forest management" and "General guidelines for conservation of biological diversity of forests in Europe" were developed in Helsinki in 1993 (Resolution H1 and H2 respectively). They were elaborated as general political guiding principles to be implemented in an integrated manner to be reflected in national guidelines and local technical solutions.

In the first part of the Resolution H1 "general guidelines", principle 9 states that "*Native species and local provenances* should be preferred where appropriate. The use of species, provenances, varieties or ecotypes outside their natural range should be discouraged where their introduction would endanger important/valuable indigenous ecosystems, flora and fauna. *Introduced species* may be used when their potential negative impacts have been assessed and evaluated over sufficient time, and where they provide more benefits than do indigenous ones in terms of wood production and other functions. Whenever introduced species are used to replace local ecosystems, sufficient action should be taken at the same time to conserve native flora and fauna".

The "Pan-European Operational Guidelines for Sustainable Forest Management" endorsed at Lisbon Ministerial Conference in 1998, were further elaborated to translating international commitments to the level of forest management practices and planning. They are directly based on Resolutions H1 and H2, and follow the structure of the six pan-European criteria that were identified as the core elements of sustainable forest management. They are divided into/addressing "Forest Management Planning" and "Forest Management Practices", focusing on basic ecological, economical and social requirements for sustainable forest management within each criterion. The Criterion no. 4 is titled "Maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems" and at 4.2 (b) states that "for reforestation and afforestation, origins of *native species and local provenances* that are well adapted to site conditions should be preferred, where appropriate. Only those *introduced species*, provenances or varieties should be used whose impacts on the ecosystem and on the genetic integrity of native species and local provenances have been evaluated, and if negative impacts can be avoided or minimised".

FOREST EUROPE has also developed, in cooperation with the Environment for Europe/Pan European Biological and Lanscape Diversity Strategy, the "**Pan-European Guidelines for Afforestation and Reforestation**"[101] with a special focus on the provisions of the UNFCCC. The Guidelines, agreed in 2008, recognise the role of sustainable forest management in climate change mitigations. They form a set of recommendations for voluntary use by national authorities and other bodies and stakeholders relevant to implement economically viable, environmentally sound and socially equitable afforestation and reforestation programmes and projects. In the section titled "Ecological Guidelines", guideline 19 affirms that "*native tree species*, provenance and varieties or ecotypes that are well adapted to site conditions should be used for afforestation and reforestation where appropriate"; guideline 20 that "the need to consider adaptation to climate change should be taken into account when choosing species, provenances and varieties for afforestation and reforestation" and guideline 21 that "species, provenances, varieties or ecotypes *outside their natural range* should only be used where their introduction would not endanger important and/or valuable indigenous ecosystems, flora and fauna. Those that are likely to be invasive should be avoided using the CBD Guiding Principle for the Prevention, Introduction, and Mitigation of Impacts of Alien Species That Threaten Ecosystems, Habitats or Species". In addition, guideline 22 states that "a precautionary approach should be taken to the use of *genetically modified trees*. Ecological socio-economic and cultural impacts, including long term effects should be analysed and a thorough, comprehensive and transparent risk assessment should be completed in accordance with the Cartagena Protocol on Biosafety. In this context, the potential impacts of genetically modified trees on native gene polls should be fully considered".

Therefore, standards, guidelines, criteria and indicators for sustainable forest management have been developed over the past few decades by intergovernmental processes, international organisations[102], certification schemes (e.g. FSC, PEFC) (Masiero et al. 2015) and national governments. These apply to all forests, including planted forests, and have resulted in forestry being recognised as an essentially sustainable land-use and 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 European level, the 46 signatories of the Ministerial Conference on the Protection of Forests in Europe agreed 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 are regularly updated and adapted to new challenges[103]. Also the International Tropical Timber Organization ITTO has developed and is revising criteria and indicators for sustainable forest management since the early 1990's[104]. Planted forests can take over many, though not all, functions that indigenous forest provide (FAO 2010c) and contribute enormously to economic benefits whist relieving the pressure on indigenous forests.

Forest certification is a voluntary sustainable forest management tool that aims to promote the sustainable management and conservation of forest ecosystems by adding market value to products generated according to environmental and socio-economic principles (Cashore et al. 2004; Auld et al. 2008; Gomez-Zamalloa et al. 2011; Meidinger 2011; Dias et al. 2013). It is based on third-party auditing of compliance with environmental and socio-economic standards, developed by governmental actors, environmental non-governmental organisations, industry associations, and social groups through participatory public processes. Forest certification relies on the willingness of a growing number of consumers to pay more for sustainably generated products and it aims to reward forest managers that follow sustainable forest management practices (Auld et al. 2008; Brown et al. 2001; Suzuki & Olson 2008).

Two forest certification systems dominate globally: the Forest Stewardship Council (FSC[105]) and the Programme for the Endorsement of Forest Certification (PEFC[106]). FSC is a global forest certification scheme. PEFC is an umbrella organization that endorses national schemes, some of which were developed

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[102] *Cf.*, New Generation Plantations (NGP), 2014. New generation plantations: review 2014 (http://newgenerationplantations.org/multimedia/file/12b486cb-ea24-11e3-9f9e-005056986313).
[103] Forest Europe http://www.foresteurope.org/sfm_criteria/criteria
[104] ITTO http://www.itto.int/sustainable_forest_management/
[105] Forest Stewardship Council (FSC), a not-for-profit international organization established in the early 1990s to promote the responsible management of the world's forests. FSC has a framework of globally applicable Principle and Criteria (FSC Std 01-001). For each of the Criteria indicators are developed for "local" certification – specific to the national legal, … circumstances. These are the national standards (i.e. the text of the P&C is in all standards exactly the same – only the indicators might differ from country to country). In some countries these national standards are specifically designed for plantation management (others for natural forest management or NTFP). In 2014/15 (after years of multi-stakeholder negotiations) the SC Std 01-001Version 5 was endorsed and it came with FSC STD 60-004 – the International Generic Indicators (IGI). So far, and probably until Oct 2015, no forest will be certified against Version 5 – all certification is based on Version 4. In P&C Std 01-001 V5 there is not any longer the "P1-9 plus P10 plantation": "In terms of vegetation, the P&C are globally applicable to all types and scales of forest including natural forests, plantations (…)". FSC STD 60-004 – distinguish only in few cases (e.g. requirements for regeneration) between plantations and other forest management types.
[106] The Pan-European Certification Scheme, which is supported by private forest owner associations, was launched in 1999 as a response to the FSC and was later renamed Programme for the Endorsement of Forest Certification Schemes [www.pefc.org] (Gulbrandsen 2005; Johansson & Lidestav 2011).

within the PEFC framework, while others existed as independent schemes for several years before PEFC was formed, e.g., American Tree Farm System (ATFS), Sustainable Forestry Initiative (SFI) and Canadian Standards Association (CSA) (Stupak et al. 2011).

FSC certification was created in 1993 to "promote environmentally appropriate, socially beneficial, and economically viable management of the world's forests" (Auld et al. 2008; https://ic.fsc.org/index.htm). FSC certification[107] comprises 10 principles and 70 criteria that cover environmental, social and economic aspects of forest management. The standard uses the CBD definition of alien species and criterion 10.3 (Principle 10 "Implementation of Management Activities") states that "The Organisation[108] shall only use alien species[109] when knowledge and/or experience have shown that any invasive impacts can be controlled and effective mitigation measures are in place".

Canada has the largest area of third-party independently certified forests (CSA, FSC, SFI) in the world. As of 2011, more than 151 million ha of Canadian forests were certified, which represents 42% of the world's forests under certification. The UK was the first country in the world to have all its state forests independently certified. Sweden was the first country to introduce a national system of certification based on FSC standards. The country has, as a result, a disproportionate part of the FSC portfolio even though its share of the total certified area has declined in recent years; from about 30 % of the world's FSC-certified forests in the beginning of the century (Boström 2003) to 12 % (Regional Totals: Forest Management Certifications, 8 October 2007, http://www.fsc-sverige.org) (Schlyter et al. 2003). The private forest owners in Sweden, who withdrew from the FSC process, opted for the Programme for Endorsement of Forest Certification (PEFC) although this alternative standard did not squeeze out the FSC standard in Sweden.

Some part of the forestry industry may perceive FSC standards as being incompatible with "plantation forestry". Importantly, a "planted forest" is not necessarily a "plantation" (as defined in FSC standard[110]) since it may have most of the principle characteristics and key elements of native forest ecosystems indigenous to an area.

Most certification standards refer to the use of appropriate provenances, varieties and species for afforestation and reforestation. Native species are always preferred, but alien species are allowed where they are substantially superior to indigenous species for reaching plantation objectives (Stupak et al. 2011)[111].

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[107] FSC 2012. FSC Principles and Criteria for Forest Stewardship. Document reference code: FSC-STD-01-001 V5-0 EN. Approval date: 10 February 2012. Forest Stewardship Council. https://ic.fsc.org/download.fsc-std-01-001-v5-0-revised-principles-and-criteria-for-forest-stewardship.a-1780.pdf [Accessed May 2014].

[108] The person or entity holding or applying for certification and therefore responsible for demonstrating compliance with the requirements upon which FSC certification is based (Source: FSC 2011).

[109] A species, subspecies or lower taxon, introduced outside its natural past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce (Source: Convention on Biological Diversity (CBD), Invasive Alien Species Programme. Glossary of Terms as provided on CBD website) Source: FSC 2012.

[110] Plantation: A forest area established by planting or sowing with using either alien or native species, often with one or few species, regular spacing and even ages, and which lacks most of the principal characteristics and key elements of natural forests. Forest Stewardship Council (2015) FSC International Standard. FSC Principles and Criteria for Forest Stewardship, FSC-STD-01-001 V5-2 EN (https://ic.fsc.org/en/certification/principles-and-criteria/the-revised-pc). One of the ten FSC principles (Principle 10) addresses plantations directly (https://ic.fsc.org/en/certification/principles-and-criteria/the-10-principles).

[111] *Cf.* also FSC STD 01-001 V4: 6.2 Safeguards shall exist which protect rare, threatened and endangered species and their habitats (…). 6.3 Ecological functions and values shall be maintained intact, enhanced, or restored, including: (a) Forest regeneration and succession; (b) Genetic, species, and ecosystem diversity; (c) Natural cycles that affect the productivity of the forest ecosystem. 6.9 The use of exotic species shall be carefully controlled and actively monitored to avoid adverse ecological impacts. 10.2 The design and layout of plantations should promote

The international FSC standard states that native species are preferred, but alien tree species are tolerated as long as their use is monitored and carefully controlled, and adverse ecological effects are avoided (Criterion 6.9). Native species are also preferred in plantations, but aliens can be used when they perform better (Criterion 10.4). In the context of FSC a genetically modified organism is defined as an "organism in which the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination or both". The use of GM trees is generally prohibited (Criterion 6.8).

FSC Papua New Guinea[112] prohibits field tests of GMOs, and some national standards give further details related to alien species and require, for example, a system to be place to monitor spontaneous regeneration outside plantation areas, unusual mortality, disease, insect outbreaks or other adverse environmental impacts (SW Australia), that alien species are only permitted in stands as single trees or in small groups (FSC Luxembourg[113]), or that they only be used in plantations or plant nurseries, or if needed to maintain historical places (FSC Russia)[114] (Stupak et al. 2011).

Native species are also generally preferred by PEFC (see the Pan European Operational Level Guidelines, PEOLG[115]), but the use of alien species is allowed as long as negative impacts can be avoided or minimised.

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the protection, restoration and conservation of natural forests, and not increase pressures on natural forests. Wildlife corridors, (...). 10.4 The selection of species for planting shall be based on their overall suitability for the site and their appropriateness to the management objectives. In order to enhance the conservation of biological diversity, native species are preferred over exotic species in the establishment of plantations and the restoration of degraded ecosystems. Exotic species, which shall be used only when their performance is greater than that of native species, shall be carefully monitored to detect unusual mortality, disease, or insect outbreaks and adverse ecological impacts.

[112] (https://ic.fsc.org/papua-new-guinea.285.htm). This is supposed to be the same for all FSC National Standards, as the P&C say: FSC STD 01-001 V4:.8 Use of biological control agents (…); Use of genetically modified organisms shall be prohibited. FSC STD 01-001 V5: 10.4 The Organization shall not use genetically modified organisms in the Management Unit. Field testing within the scope of the certificate is therefore also not permitted – some national indicators stress this, others not. But the result is the same: No GMO in any FSC certified FMUs

[113] http://www.fsc-lux.lu/

[114] Luxemburg and Russia FSC are examples where the national standard requires more than the global P&C. Similarly, e.g., FSC in Germany, where they say no plantations, except for Christmas trees, and not larger than 5 ha resp. 5% of the forest management unit. FSC Germany: 6.9.1 Tree species that are not part of natural forest associations (including exotic species) are positioned as single trees or small groups to an extent which does not jeopardize the long-term development of the stands into natural forest associations. 6.9.1.1 If the proportion of tree species that are not part of natural forest associations exceeds 20% of the planned stocking goal for the specific forest management unit, the forest enterprise professionally justifies that the development towards the natural forest plant association is not at risk. 6.9.1.2 Such proof is not necessary for nurse crop that is not part of natural forest associations, if at most 20% of the stocking unit is taken over as temporary mixture. 6.9.1 Tree species that are not part of natural forest associations (including exotic species) are positioned as single trees or small groups to an extent which does not jeopardize the long-term development of the stands into natural forest associations..9.2 Positioning of tree species that are not part of natural forest associations (including exotic species) in areas that fall under principle 9, is only feasible insofar as it is explicitly permitted by the respective environmental sector planning (e.g. protective area regulation, Natura 2000 management plan). For the Christmas tree planted forests it says: 10.4.3 Exotic species are attentively monitored to avoid negative impacts on the forest ecosystem. The forest enterprise makes sure that negative impacts are avoided through the use of appropriate measures. Additionally, the addenda to FSC Germany, at 6.9.1.1 states that non-native tree species are only cultivated in Germany when they have been proven ecologically non-invasive through years of experience or with comparable data from pilot projects. That is, they must coexist with native tree species and not tend toward dominance. They must support an abundant level of plant and animal life that is not significantly under those of natural forest plant associations. They must contribute to the performance of the forest's ecological function and regenerate naturally under existing environmental conditions (https://ic.fsc.org/germany.278.htm).

[115] (http://pefc.org/images/documents/MCPFE_PEOLG.pdf).

Some national standards have requirements identical or similar to FSC (PEFC Switzerland and UK and Malaysian MTCC). Some focus on protection against invasive alien species (CertForChile Plantations, PAFC Gabon and SFI[116] draft 2009), and the SFI draft 2009, in agreement with PEOLG, requires the use of aliens to be minimised. Similar to FSC Russia, FCR Russia only accepts alien species in plantations, and they are also widely accepted for plantations in Australia (Australian AFS) (Stupak et al. 2011). CertForChile Native Forests tolerates them in degraded native forests, with only limited acceptance in conservation areas. PEFC Sweden requires that the use of alien species be in accordance with current legislation and regulations. The use of GM trees is not clearly addressed in PEFC standard-setting documents, but several PEFC-endorsed schemes prohibit the use of GM trees either generally (e.g., PEFC Austria, Estonia, Germany, Poland, Norway, Portugal 2009, Switzerland, UK, MTCC Malaysia and PAFC Gabon) or temporarily (CertForChile Plantations, PEFC Latvia and Sweden), or allow them with some reservations (Australian AFS, Brazilian Cerflor, PEFC France and Wallonia in Belgium). The new SFI draft 2009 requires research on GMOs via forest tree biotechnology to adhere to all applicable federal, state, and provincial regulations and international protocols. Similar to land-use conversion issues, Canadian CSA requires that aliens and GM trees be discussed with the public (Stupak et al. 2011). In order to continue using improved material, including those derived from biotechnology, SFI specifies that program members must use recognised scientific methods to track their plantations and follow national regulations as well as other international protocols (Morissette 2012).

4.5 European initiatives and legislation

4.5.1 Habitat Directive – Natura 2000

The Habitats Directive[117] (together with the Birds Directive) forms the cornerstone of Europe's nature conservation policy. It is built around two pillars: the Natura 2000 network of protected sites and the strict system of species protection. All in all, the directive protects over 1,200 animals and plant species and over 200 habitat types (e.g. special types of forests, meadows, wetlands, etc.), which are of European interest. According to Article 22.b, in implementing the provisions of this Directive, Member States shall: "ensure that the deliberate introduction into the wild of any species which is *not native* to their territory is regulated so as not to prejudice natural habitats within their natural range or the wild native fauna and flora and, if they consider it necessary, prohibit such introduction. The results of the assessment undertaken shall be forwarded to the committee for information".

BOX 4.7.1 - Management of Natura 2000 habitats: the 9360 Macaronesian laurel forests (Laurus, Ocotea).

Widespread throughout mainland Europe before the Ice Ages (during the Neogene), the humid to hyper-humid evergreen forests known as laurel forests were driven close to extinction during cold climatic periods. Now restricted to the cloud belt of the Macaronesian islands, they grow in deep soils at between 500 and 1,500 m. Macaronesian laurel forests have been intensively transformed since the fifteenth century when the original forest area was largely razed to create farmland and degraded due to forest exploitation and livestock farming. Already significantly reduced in extent, in some areas habitat is being further degraded by exploitation and livestock stocking. In some cases, habitat reduction has led to fragmentation, threatening habitat diversity and leading to species extinction. Other current threats are the spread of alien species, a major concern in the Azores and Madeira, and forest fires, especially serious in the Canary Islands. Native forests have been cleared for pastures but have also been replanted since 1940's with planted forests of alien tree species such as *Acacia* spp. and *Cryptomeria japonica* (Hervías Parejo et al. 2014).

[116] Sustainable Forestry Initiative (http://www.sfiprogram.org).
[117] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Official Journal L 206, 22/07/1992 P. 0007 – 0050 [http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm].

Where necessary, the type of management is chosen according to the degree of habitat development and to local features. The most common situations are: selective cuttings to improve regeneration in stands that have been heavily exploited, conversion of planted forests into laurel forests, control of invasive alien species and recovery of specific threatened species.

In the case of Tenerife (Canary Islands), Arevalo et al. (2011) suggest that conservation and restoration efforts have not to be devoted to invasion control but to removal of current *E. globulus* plantations and gradual thinning of *P. radiata*, with the final objective of converting the current planted forests to forests resembling the laurel forests in structure and composition.

Management of Natura 2000 habitats[118] is a project launched by the European Commission in January 2007 aimed at defining best practices for management of habitat types included in Annex I of the Habitat Directive (92/43/EEC) that need active recurring management. Twenty-six habitat types that are representative of different bio-geographical regions have been considered. This scenario motivated several LIFE European financed programs aimed at laurel forest restoration.

4.5.2 The Plant Health Regime in the European Union

European Union rules on plant health[119] aim to protect crops, fruit, vegetables, flowers, ornamentals and forests from harmful pests and diseases (harmful organisms) by preventing their introduction into the EU or their spread within the EU. This aim helps to contribute to the protection of public and private green spaces, forests and the natural landscape. Although the man focus is the control of harmful organisms (pests) within the Community, as a result, the introductions of some tree species might be restricted or specifically regulated due to phytosanitary reasons[120].

4.5.3 The Biodiversity Strategy of the European Union

In 2011, the European Commission adopted a new strategy that lays down the framework for EU action over the next ten years in order to meet the 2020 biodiversity headline target set by EU leaders in 2010[121].

The Target 5 of the EU Biodiversity strategy requires that “by 2020 Invasive Alien Species (IAS) and their pathways are identified and prioritised, priority species are controlled or eradicated, and pathways are managed to prevent the introduction and establishment of new IAS”. Within the Action 16 of the Target 5 the EU has committed itself a dedicated legislative instrument on the issue.

[118] http://ec.europa.eu/environment/nature/natura2000/management/best_practice_en.htm

[119] EU rules on plant health form the EU Plant Health Regime which the Commission has reviewed for the first time since 1977. he Commission has proposed a new EU plant health regulation in May 2013. Council Directive 2000/29/EC (Council Directive 2000/29/EC of 8 May 2000, on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community) provides the basis for this aim. The general principles are based upon provisions laid down in the International Plant Protection Convention (IPPC). Directive 2000/29/EC is supported by a number of Control Directives and Emergency Measures.

[120] The Commission Implementing Decision of 1 March 2012 as regards emergency measures to prevent the introduction into and the spread within the Union of *Anoplophora chinensis* (Forster) (notified under document C(2012) 1310) (2012/138/EU - Official Journal of the European Union L 64/38, of 3 March 2012) banned the introduction of that plants of *Acer* spp. into the Union until 30 April 2012. Under EU Plant Health Regime some tree species are prohibited to be imported from non-EU countries (as listed in Annex 111), e.g. imports of *Chamaecyparis* spp. are banned from countries outside of the EU.

[121] http://ec.europa.eu/environment/nature/info/pubs/docs/factsheets/Biod%20Strategy%20FS.pdf

4.5.4 The EU Regulation on invasive alien species

A Regulation on invasive alien species has been adopted by the European Parliament and by the Council on the 22 October 2014[122] and came into force on 1 January 2015. This legislation seeks to address the problem of invasive alien species in a comprehensive manner so as to protect native biodiversity and ecosystem services, as well as to minimise and mitigate the human health or economic impacts that these species can have[123].

The legislation foresees three types of interventions; prevention, early warning and rapid response, and management. A list of invasive alien species of Union concern will be drawn up with Member States using risk assessments and scientific evidence by the 2015. Species on the list may not be intentionally brought into the territory of the EU, nor may they be kept, bred, transported to, from or within the Union, placed on the market, grown or released into the environment.

The regulation also establishes a surveillance system for early detection and measures for rapid eradication. Furthermore, member states must provide for penalties if the regulation is not correctly applied.

The initial list of invasive alien species of Union concern pursuant to Article 4(1) of the regulation was adopted on the 13 July 2016[124]. This first list of 37 invasive alien plant species of Union Concern does not include any alien tree. However, the risk assessment of *Acer negundo* is under consideration for a possible inclusion in the Union List at its next update.

4.5.5 Forest policies in the European Union

Forest policies in the European Union are implemented by Member States within a clearly defined framework of established ownership rights and with a long history of national and regional laws and regulations based on long term planning. Although the Treaties for the European Union make no provision for a common forest policy, there is a long history of EU measures supporting certain forest-related activities, coordinated with Member States mainly through the Standing Forestry Committee (European Commission 2003).

Forests are affected by a broad array of Community policies and initiatives arising from diverse EU sectorial policies (e.g., Schmithüsen et al. 2000). For several decades now, environmental forest functions have attracted increasing attention mainly in relation to the protection of biodiversity and, more recently, in the context of climate change impacts and policies. In public perception, apart from the traditional production of wood and other forest products, forests are increasingly valued for their role as public amenities, biodiversity reservoirs, regulators of climate and local weather, sources of clean water, protection against natural disasters and renewable energy sources[125] (European Commission 2003).

In 1992, the European Commission launched a programme to increase afforestation activities on farmland[126]. The purpose of the program was to reduce the costs of agricultural subsidies. Landowners willing to convert agricultural land into forest or woodland received afforestation grants which included a cost support for maintenance during the first critical years as well as forest premium compensation for the income lost from agricultural products (Dohrenbusch & Bolte 2007). Within the first decade of the programme's launch, about a million ha were afforested in the European Community, mainly in Spain,

[122] Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species, published in the Official Journal of the European Union, L 317, 4.11.2014, p. 35–55 (http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1415726405933&uri=CELEX:32014R1143).

[123] http://ec.europa.eu/environment/nature/invasivealien/index_en.htm

[124] Commission Implementing Regulation (EU) 2016/1141 of 13 July 2016 adopting a list of invasive alien species of Union concern pursuant to Regulation (EU) No 1143/2014 of the European Parliament and of the Council.

[125] http://ec.europa.eu/environment/forests/fpolicies.htm

[126] Council Regulation No 2080/1992 of 30 June 1992(OJ L215, 30.7.1992). See also the Reg.No. 2078/1992.

Portugal, and Ireland. Countries implementing this program were allowed some flexibility, within a limited framework, to modify tree species (including non-native trees), grants and premiums permitted[127] (Dohrenbusch & Bolte 2007; Lefebvre et al. 2012).

The EU Forestry Strategy[128], first adopted in 1998, put forward as its overall principles the application of sustainable forest management and the multifunctional role of forests. In line with the principle of subsidiarity, meaning that every administrative decision should always been made at the most appropriate level taking into account the specific local circumstances, this Strategy seeks to establish a coherent framework of forest-related actions at EU level. It also aims to improve the linkages and co-ordination between different policy areas as well as the coherence with the forest policies of the Member States (European Commission 2003).

The contents of the Council Directive 1999/105/EC of 22 December 1999 on the marketing of forest reproductive material are also noteworthy[129].

In 2006 the EU underpinned its support for sustainable forest management and the multifunctional role of forests by adopting an EU Forest Action Plan[130]. The plan was a framework for forest-related measures and was used to coordinate EU initiatives with the forest policies of the Member States. There were 18 key actions proposed to be implemented jointly with the Member States during the period 2007-2011.

In 2014 the EU adopted a revised Forest Strategy[131] which responds to the new challenges facing forests and the forest sector. In the Strategy and in the accompanying documentation, it is stressed that European forests are threatened by biotic and abiotic agents, such as insects and other pests, diseases,

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[127] In Ireland, for example, afforestation grants differed between 2,000 Euro and 5,000 Euro per hectare, dependent on tree species composition. Plantations of conifers such as Sitka spruce (*Picea sitchensis*), for example, or lodgepole pine (*Pinus contorta*), with some 2,500 plants per hectare, attracted a grant of about 2,000 Euro plus 700 Euro for maintenance. For broadleaved species, such as the common oak (Quercus robur) or the European beech (*Fagus sylvatica*), the afforestation grant was more than 5,000 Euro along with maintenance compensation of 1,600 Euro. A forest premium is paid up to 20 years for farmers but only 15 years for non-farmers (Dohrenbusch & Bolte 2007).

[128] Council Resolution of 15 December 1998 on a forestry strategy for the European Union. (OJ C56, 26.2.1999).

[129] [Official Journal L 011, 15/01/2000 P. 0017 - 0040]. This Directive contains specific definitions that – although solely referring to the purposes of the Directive itself - are somewhat different from the generally agreed definitions of alien and native status (*Cf.* Article 2). "… (d) Autochthonous and indigenous means either of the following: (i) Autochthonous stand or seed source: An autochthonous stand or seed source is one which normally has been continuously regenerated by natural regeneration. The stand or seed source may be regenerated artificially from reproductive material collected in the same stand or seed source or autochthonous stands or seed sources within the close proximity; (ii) Indigenous stand or seed source: An indigenous stand or seed source is an autochthonous stand or seed source or is a stand or seed source raised artificially from seed, the origin of which is situated in the same region of provenance. (e) Origin: For an autochthonous stand or seed source, the origin is the place in which the trees are growing. For a non-autochthonous stand or seed source, the origin is the place from which the seed or plants were originally introduced. The origin of a stand or seed source may be unknown. (f) Provenance: The place in which any stand of trees is growing. (g) Region of Provenance: For a species or sub-species, the region of provenance is the area or group of areas subject to sufficiently uniform ecological conditions in which stands or seed sources showing similar phenotypic or genetic characters are found, taking into account altitudinal boundaries where appropriate … ".

[130] The Action Plan does not refer directly to the risk posed by invasive alien species. Anyway, the Key action 7 is titled: Contribute towards achieving the revised Community biodiversity objectives for 2010 and beyond. It can be considered as a commitment to the principles aiming to tackle invasive alien species that are present in the recalled document, i.e. the Commission Communication of 22 May 2006 "Halting the loss of biodiversity by 2010 - and beyond - Sustaining ecosystem services for human well-being" [COM(2006) 216 final - Not published in the Official Journal].

[131] Brussels, 20.9.2013, COM(2013) 659 final - http://ec.europa.eu/agriculture/forest/strategy/index_en.htm

grazing and invasive alien species, windstorms, forest fires, droughts, floods and avalanches. Importantly, this Strategy does not list the forest sector as a potential pathway and driver for the introduction and dissemination of new invasive alien species. In 2014 The Council adopted conclusions which welcome the new EU Forest Strategy, underlining the need to enhance forests' adaptive capacities and resilience to climate change, to reduce the risks and effects of forest fires, pests and diseases and invasive alien species and other disturbances with preventive measures.

Rural development policy is part of the EU's common agricultural policy (CAP) which has been the main instrument for implementing forestry measures in recent years. In this context, financial support from the EU for forestry measures, not including direct funding by the Member States, amounted to EUR 4 800 million for the period 2000–2006 (almost 10 % of the rural development budget, source: EC 2011 – Eurostat).

High Nature Value (HNV) forestry can be defined as all natural forests and those semi-natural forests in Europe where the management (historical or present) supports a high diversity of native species and habitats and/or which support the presence of species of European, and/or national, and/or regional conservation concern (European Commission 2013). The maintenance and enhancement of HNV farming and forestry systems is a strategic objective of the European Rural Development Policy and the Managing Authority has to monitor and assess the effectiveness of rural development measures as regards this objective. In order to perform the assessment, the European Commission has envisaged three indicators for HNV farmlands and forestry, in the context of the Common Monitoring and Evaluation Framework (CMEF) for Rural Development 2007-2013 (see EC Reg. no. 1974/2006): baseline indicator 18, result indicator 6 and impact indicator 5. The application of these indicators is a challenging task, mainly due to the complexity of the concept to be measured (Pignatti et al. 2012).

4.5.6 The EU Energy Policy

Bio-energy is seen as one of the key options to mitigate greenhouse gas emissions and substitute fossil fuels (e.g., Faaij 2006). As a result, the large-scale production of renewable heat, electricity and transport fuel from biomass is an important component in many climate change mitigation and energy supply scenarios and a strategically important option for increasing the global uptake of renewable energy (Slade et al. 2014). Yet the practicalities of accelerating deployment are mired in controversy over the potential resource conflicts that might occur, particularly over land, water, biodiversity conservation, soil fertility (Slade et al. 2014; Somerville et al. 2010) and forest conservation (Biello 2011). This calls into question whether policies to promote bioenergy are always and everywhere justified (Slade et al. 2014; Searle & Malins 2014) and if they could constitute a further pathway for the introduction of new invasive alien trees.

At both the international level and the EU level there are several ongoing initiatives seeking more sustainable forest management also in relation to bioenergy from forests and planted forests, such as the various international processes on SFM based on C&I, reducing emissions from deforestation and forest degradation (REDD+) or forest law enforcement, governance and trade (FLEGT). At the European level, the revision of the European Forest Strategy and the ongoing process to establish a legally binding agreement on forests in Europe must be underlined. In addition to those general provisions for forests and forestry, several specific initiatives for woody bioenergy have been developed with the aim of guaranteeing overall environmental sustainability (Fritsche et al. 2014; Repo et al. 2015)[132].

[132] Cf. Also the BASIS project on Biomass Availability and Sustainability Information System (http://www.basisbioenergy.eu/fileadmin/BASIS/D4.1.Sustainability_Criteria_for_Bioenergy.pdf.

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6. Annexes

6.1 Definitions – Glossary

The terminology used in legislation and in the scientific and technical literature when discussing alien and invasive tree species can be complex and confusing as many of the terms have been used in different ways by different authors. Unless referenced, definitions follow FAO, CBD, Richardson et al. (2011), Blackburn et al. (2011), Jeschke et al. (2014), the Code of Conduct on Horticulture and Invasive Alien Plants (Heywood & Brunel 2009, 2011) and the European Code of Conduct for Botanic Gardens on Invasive Alien Species (Heywood & Sharrock 2013).

Alien species

A species, subspecies or lower taxon, introduced outside its natural past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce (Decision VI/23 of the Conference of the Parties to the CBD, Annex, footnote to the Introduction). *Cf.* also the Regulation (EU) No. 1143/2014 of the European Parliament and of the Council, of 22 October 2014, on the prevention and management of the introduction and spread of invasive alien species (Article 3 – Definitions: 'alien species' means any live specimen of a species, subspecies or lower taxon of animals, plants, fungi or micro-organisms introduced outside its natural range; it includes any part, gametes, seeds, eggs or propagules of such species, as well as any hybrids, varieties or breeds that might survive and subsequently reproduce).

In the context of the present Code of Conduct the terms alien, non-native, exotic and introduced (tree) are considered as equivalent. In accordance with the CBD definition, the term alien has exclusively a biogeographical meaning, i.e. it refers to a species, subspecies or lower taxon, introduced outside its natural past or present distribution. As such, the term alien does not include any negative or positive evaluation of the species. Only a small percentage of all the alien species are, or may become after some time, invasive alien species (COP 6 Decision VI/23 “Alien species that threaten ecosystems, habitats or species”). Importantly, an alien species is “introduced outside its natural past or present distribution” deliberately or accidentally by man. The Recommendation No. 142 (2009) of the Standing Committee (Convention on the Conservation of European Wildlife and Natural Habitats), adopted on 26 November 2009, interpreting the CBD definition of invasive alien species to take into account climate change “Recommends Contracting Parties to the Convention and invites Observer States to: 1. interpret the term “alien species” for the purpose of the implementation of the European Strategy on Invasive Alien Species as not including native species naturally extending their range in response to climate change” (Cf. Section 4.6.2 in this Code). As a results, also past mass migratory events in forest tree populations, postglacial recolonization routes and similar events are not considered in the definition of alien tree species. The Code of Conduct focuses on alien trees deliberately or accidentally introduced by man outside its natural past or present distribution, where “past” refers to the definition of “neophytes” (i.e. introduced after the 1,500) as used in the CBD context and defined by Pyšek et al. (2004).

Afforestation

Afforestation is the act of establishing forests through planting and/or deliberate seeding on land that, until then, was not classified as forest (FAO 2010a, 2015a, 2015b). Reforestation on the other hand, takes place in areas that already are classified as forest and does not imply any change of land use from a non-forest use to forest.

Ancient forest

An ancient forest is a forest that has existed continuously since at least a specified date (threshold date), selected on the availability of historical land-use information and differing between studies and countries (Hermy et al. 1999; Verheyen & Hermy 2007).

Bioenergy

Bioenergy[133] is the conversion of biomass resources into useful energy carriers including heat, electricity and transport fuels. Biomass is derived from different types of organic matter: energy plants (oilseeds, plants containing sugar) and forestry, agricultural or urban waste including wood and household waste. Biomass can be used for heating, for producing electricity and for transport biofuels. Biomass can be solid (plants, wood, straw and other plants), gaseous (from organic waste, landfill waste) or liquid (derived from crops such as wheat, rapeseed, soy, or from lignocellulosic material).

Black List

A Black List identifies those alien species whose introduction is prohibited due to their potential adverse effects on the environment or human, animal or plant health. Such lists can be a significant component of an invasive alien species prevention regime since they clearly state which species are banned from import. Black lists are the most common type of listing mechanism and are found in a range of countries. Such lists are most useful to prevent intentional introductions at the pre-border stage, as a potential exporter can check the relevant lists to see if the species in question is allowed or banned from imports, or, for unlisted species, request permission to import. This provides increased transparency and predictability for exporters before any products are gathered, packaged and shipped. Lists can also be used at the border by inspection and quarantine agents for purposes of searching baggage, package and cargo.

The success of such a listing system is inherently related to its adaptability and flexibility, particularly with regard to processing new submissions and proposals for movement from one list to another. The three types of lists are referred to as black, white and grey lists, and are sometimes used individually and sometimes in combination. More in general, black lists are nowadays not only restricted to the pre-import stage.

CBD - Convention on Biological Diversity

Signed by 150 government leaders at the 1992 Rio Earth Summit, the Convention on Biological Diversity is dedicated to promoting sustainable development. Conceived as a practical tool for translating the principles of Agenda 21 into reality, the Convention recognizes that biological diversity is about more than plants, animals and microorganisms and their ecosystems – it is about people and our need for food security, medicines, fresh air and water, shelter, and a clean and healthy environment in which to live (http://www.cbd.int/convention/default.shtml).

Eradication

The extirpation of an entire population of an alien species within a designated management unit. When a species can be declared eradicated (that is, how long a period of time after the management intervention) depends on the species and the situation and must take into account factors such as seed-bank longevity (for plants). Eradication success should be stated in terms of confidence limits (e.g. 1-5 % confidence) that the species is not present. Eradication is possible in many cases, but there are no clearly documented cases of the eradication of an alien tree species (van Wilgen & Richardson 2014).

FRA – Forest Resources Assessment

FAO has been monitoring the world's forests at 5 to 10 year intervals since 1946. The Global Forest Resources Assessments (FRA) are now produced every five years in an attempt to provide a consistent approach to describing the world’s forests and how they are changing, e.g. FRA 2010, 2015. The scope and content of the global assessments have evolved over time to respond to changing information needs (FAO 2015a, 2015b).

[133] http://ec.europa.eu/energy/renewables/bioenergy/bioenergy_en.htm

Impact

The description or quantification of how an alien invasive species affects the physical, chemical and biological environment. Many invasive alien species have substantial effects on the ecosystems into which they have been introduced, including significant changes in native species extinction probabilities, genetic composition, behaviour patterns, richness and abundance, as well as altering phylogenetic and taxonomic diversity, trophic networks, ecosystem productivity, nutrient cycling, geomorphology, hydrology, habitat structure and various components of disturbance regimes (Hawkins et al. 2015).

Invasive alien species

Alien species that sustain self-replacing populations over several life cycles, produce reproductive offspring, often in very large numbers at considerable distances from the parent and/or site of introduction, and have the potential to spread over long distances. Invasive species are a subset of naturalized species; not all naturalized species become invasive and threaten or adversely impact upon biodiversity and related ecosystem services.

Cf. also the Regulation (EU) No. 1143/2014 of the European Parliament and of the Council, of 22 October 2014, on the prevention and management of the introduction and spread of invasive alien species (Article 3 – Definitions: 'invasive alien species' means an alien species whose introduction or spread has been found to threaten or adversely impact upon biodiversity and related ecosystem services).

Invasiveness

The features of invasive alien plant species, such as their life-history traits and modes of reproduction, that define their capacity to invade, i.e. to overcome various barriers to invasion. The level of invasiveness of a species can change over time due to, for example, changes in genetic diversity through hybridization, introgression, or the continued arrival of new propagules of the same species that is already established in a region, but from new and different (meta)populations, such that genetic diversity may increase.

Management of invaded habitat as a ''novel ecosystem''

Ensuring the continued and sustainable delivery of key functions and services, in some cases accepting that invasive alien species fulfil useful purposes, especially where conditions are modified to the extent that the return of native species is unrealistic (van Wilgen & Richardson 2014). Where habitats have been substantially modified through multiple human factors, removing invasive alien trees and restoring native dominated communities and ecosystem functions is sometimes either impossible or undesirable. For instance, in riparian ecosystems in many parts of the world that are heavily invaded by alien trees, physical conditions have been modified to such an extent that native elements can no longer establish or survive, even when the invasive trees are removed. In such cases, manipulating of the density and abundance of key alien species to achieve desired ecosystem functions and services is an appropriate, pragmatic management goal (Richardson et al. 2007).

Pest

According to the International Plant Protection Convention (IPPC) a pest is "any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products", while a quarantine pest is "a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled". As a consequence, considering that potential economic importance can account for environmental concern (according to the supplement the International Standard on Phytosanitary Measures no. 5 Glossary of phytosanitary terms), the IPPC definition of a quarantine pest covers much of what is considered an invasive alien species under the CBD. Differences arise from the fact that a quarantine pest does not necessarily have to be alien, threaten biodiversity, may only affect agriculture, and that an invasive alien plant may not be considered a quarantine pest if it is widely distributed (Heywood & Sharrock 2013).

Polluter Pays Principle (PPP)

The Polluter-Pays Principle (PPP) was adopted by The Organisation for Economic Co-operation and Development in 1972 as an economic principle for allocating the costs of pollution control. Under the 1972 and 1974 OECD Recommendations, the Polluter-Pays Principle means that the polluter should bear the "costs of pollution prevention and control measures", the latter being "measures decided by public authorities to ensure that the environment is in an acceptable state". The principle is laid down in the Rio Declaration (CBD) and in Directive 2004/35/EC of the European Parliament and of the Council of 21 April 2004 on environmental liability.

Reforestation

Reforestation refers to the re-establishment of forest through planting and/or deliberate seeding on land classified as forest, for instance after a fire, storm or following clearfelling (FAO 2010a).

Residence time

The time since the introduction of an alien species to a region; since the introduction date is usually derived from post-hoc records and is likely inaccurate, the term minimum residence time has been suggested. The extent of invasion of alien species generally increases with increasing residence time as species have more time to fill their potential ranges.

Risk assessment (RA)

The estimation of the quantitative or qualitative value of risk (the likelihood of an event occurring within a specified time frame and the consequences if it occurs). In the context of invasion ecology, RA is undertaken to evaluate the likelihood of the entry, establishment and spread of an alien species (intentionally or accidentally) in a given region, negotiating given barriers in the naturalization-invasion continuum, and the extent and severity of ecological, social and economic impacts. Risk assessment is defined by article 5 of the WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement). Risk assessment is one of the three components of Risk Analysis (risk assessment, risk management and risk communication).

6.2 The most frequently listed alien tree species in Europe

Species	DK	BL	IT	IR	Malta	NW	PT	SW	EPPO
Abies alba						HI			Invasive
Abies balsamea						LO			
Abies concolor						PH			
Abies grandis						PH			
Abies koreana						LO			
Abies lasiocarpa						LO			
Abies mariesii						NK			
Abies procera						LO			
Abies sibirica						PH			
Acacia cyanophylla							Annex I		
Acacia cyclops					MPI				
Acacia dealbata				Potential			Annex I	Watch-List	Invasive
Acacia farnesiana							Annex I-III		
Acacia karroo (= Vachellia karroo)					MPI		Annex I		
Acacia longifolia							Annex I		
Acacia mearnsii							Annex I		
Acacia melanoxylon				Potential			Annex I		
Acacia pycnantha							Annex I		
Acacia retinodes							Annex I		
Acacia saligna					MPI				
Acer campestre						LO			
Acer negundo		WL B2	Black-List			LO			
Acer platanoides				Uncertain					
Acer pseudoplatanus				Amber-List		SE			
Aesculus hippocastanum						PH			
Ailanthus altissima		BL A2	Black-List	Uncertain	MPI		Annex I	Black-List	Invasive
Casuarina equisetifolia					MPI				
Chamaecyparis lawsoniana						LO			
Eucalyptus camaldulensis					MPI				
Larix decidua						SE			
Paulownia tomentosa			Black-List	Potential				Watch-List	
Picea sitchensis				Uncertain		SE			
Pinus contorta ssp. contorta var. contorta	Black-List			Uncertain		PH			
Pinus contorta ssp. contorta var. latifolia	Black-List								

Pinus contorta ssp. murrayana	Black -List							
Pinus mugo ssp. mugo	Black -List				SE			
Pinus mugo ssp. mugo x rotundata	Black -List							
Pinus nigra			Black-List		LO			
Populus alba					LO			
Prunus laurocerasus		WL B1	Black-List				Black-List	
Prunus serotina	Black -List	BL A3	Black-List		HI		Black-List	Invasive
Pseudotsuga menziesii				Uncertain	LO			
Quercus cerris				Uncertain	LO			
Quercus rubra		WL B3	Black-List	Uncertain	LO			
Robinia pseudoacacia	Obs-List	WL B3	Black-List	Uncertain	HI	Annex I	* Black-List	
Rhus typhina		WL B1			NK		Black-List	
Salix viminalis				Uncertain	PH			
Thuja plicata					LO			

*Table 1 - The alien trees most frequently listed (within different categories) in different European countries (DK = Denmark, BL = Belgium, IT = Italy, IR = Ireland, NW = Norway, PT = Portugal, SW = Switzerland, EPPO = EPPO Region). The table includes both tree species alien "to" and alien "in" Europe or in the EPPO region. The term "alien in" is used for those tree species that are native in some European countries but are considered alien in other European countries (e.g. Populus alba). Plants names are reported exactly as they are found in the original source, regardless of synonyms or invalid names (e.g. Acacia cyanophylla Lindl. is a synonym for Acacia saligna (Labill.) Wendl.; Pinus contorta ssp. murrayana should be indicated as Pinus contorta var. murrayana). * see comment below in the paragraph regarding Switzerland.*

In **Denmark**, non-native species are not explicitly dealt with under the Forestry Act, but through some of the statutory orders affiliated with this law various lists of accepted trees/shrubs are maintained by the Danish Nature Agency (Madsen et al. 2014).

The **Belgian** Forum on Invasive Species (http://ias.biodiversity.be/) provides information on Alert, Black and Watch lists of invasive species in Belgium on its web site (Branquart 2014).

In **Italy** two regional Black Lists are in force, i.e. in Lombardy (LR no. 10, 31 March 2008; DGR VIII/007736, 24 July 2008) and Piedmont (Determinazione Regionale DB0701 no. 448, 25 May 2012; DGR 46-5100, 18 December 2012) (Brundu 2008).

Invasive Species **Ireland**, a joint venture between the Northern Ireland Environment Agency and the National Parks and Wildlife Service (http://invasivespeciesireland.com/), produces lists of invasive and non-native species in Ireland and Northern Ireland using the Non-native species APplication based Risk Analysis (NAPRA).

The **Malta**[134] Environment and Planning Authority (MEPA, http://www.mepa.org.mt/) has commissioned two studies to list alien plant and animal species found in the Maltese Islands and to identify the invasive types which require further action such as eradicating or controlling their spread in protected areas.

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[134] Under Part III of the "Trees and Woodlands Protection Regulations, 2011" (Legal Notice 200 of 2011) the species included in Schedule III are deemed to be species causing damage to biological diversity of trees or woodlands in Malta, or to the natural environment in general (Regulation 8, paragraph 1). The species in question are *Acacia cyclops*, *Acacia saligna* [=*Acacia cyanophylla*], *Vachellia karroo* [= *Acacia karroo*], *Ailanthus altissima*, *Eucalyptus camaldulensis*, *Eucalyptus gomphocephala*, *Leucaena leucocephala* [= *Acacia leucocephala*; *Albizzia lebbek*], *Pittosporum tobira*, *Ricinus communis* and *Schinus terebinthifolius*. Regulation 8, paragraph 2, prohibits the propagation, sowing, import, export, transportation, selling or exchanging any of these species. Regulation 9 on improvement measures also applies to the species listed in Schedule III of Legal Notice 200 of 2011. Apart from these species, Regulation 10 enables the Competent Authority to stop the transport and importation of trees, which may endanger the biological diversity of trees or woodlands in Malta, or other reasons as stated in the provision. In this respect, it should be noted that these species listed in the Regulations have all been proven to have an adverse impact on Maltese biodiversity. The Regulations are available at: http://www.justiceservices.gov.mt/DownloadDocument.aspx?app=lom&itemid=11493&l=1

Afforestation (and deforestation) is also included in Schedule IA, that is "Projects which require an Environmental Impact Statement or an Environmental Planning Statement", in the "Environmental Impact Assessment Regulations, 2007, as amended" (Legal Notice 114 of 2007, as amended by Legal Notices 425 of 2007, 438 of 2011 and 211 of 2015). These are available at: http://www.justiceservices.gov.mt/DownloadDocument.aspx?app=lom&itemid=11556&l=1

In 2002, the then Planning Authority (now MEPA) published the "Guidelines on Trees, Shrubs and Plants for Planting and Landscaping in the Maltese Islands", available at: https://www.mepa.org.mt/LpDocumentDetails?syskey=244. The 2002 guidelines aim to: (1) promote environmentally-sound planting and soft-landscaping by guiding interested agencies (e.g. Government Departments, Local Councils, voluntary organisations) and the general public; (2) encourage incentives for environmentally-compatible improvements in planting and landscaping projects, and to deter unsustainable, or environmentally-damaging practice; (3) further promote the demand for the propagation of suitable indigenous vegetation, and encourage Governmental and private nurseries to satisfy such demand; and (4) enable clients/developers, as well as their architects and consultants, to produce appropriate landscaping layouts and drawings for specific development projects. Appendix V to the 2002 guidelines lists those species that are unacceptable in rural areas. This list includes tree species that are invasive in the Maltese Islands. More recently, MEPA also published in 2009, the illustrated booklet (not available in digital format) entitled "Common Species used for Landscaping in the Maltese Islands". This booklet covers soft landscaping (interventions based on planting) and classifies the plant species that are illustrated into the following categories: (a) plants that are acceptable to use in landscaping: large trees; smaller trees and larger shrubs; and smaller shrubs and creepers; (b) trees for particular locations; (c) alien species.

Within the context of invasive alien plants, MEPA adopted on 7 March 2013 the publication entitled "Guidelines on managing non-native plant invaders and restoring native plant communities in terrestrial settings in the Maltese Islands" available at: http://www.mepa.org.mt/guidelines-alienplants. The purpose of these guidelines is to: (1) assist the planning and implementation of management programmes, aimed at counteracting the spread of existing plant invaders in important natural and semi-natural areas as well as rural areas, where the removal of non-native plants is desired; and (2) assist the design and implementation of native plant conservation translocations (such as plant reintroductions or reinforcements), aimed at reinstating native plant communities to a favourable conservation status or reinstate an ecological function. The document also serves as guidance to be followed when drawing up method statements on the removal of invasive plants and when implementing conditions that accompany development permits. The invasive woody species (among other plants) addressed in the Guidelines are: *Acacia cyclops*, *Vachellia karroo*, *Acacia saligna*, *Ailanthus altissima*, *Casuarina equisetifolia*, *Eucalyptus* spp., *Leucaena leucocephala*, *Nicotiana glauca*, *Ricinus communis* and *Schinus terebinthifolius*.

The **Norwegian** Biodiversity Information Centre is responsible for assessing the ecological impacts associated with species that are non-native to Norway (alien species) and to provide an overview of alien species found in Norway (Gederaas et al. 2012).

In 1999, the **Portuguese** legislation addressed the problem of invasive alien species with the Decreto-Lei no. 565/99, of the 21st December 1999, which regulates the introduction of non-native species. This law lists the introduced alien species in Portugal, indicating which are considered invasive and prohibiting the introduction of new species (with some exceptions). Furthermore, the legislation prohibits the possession, cultivation, growing and the trade of species that are considered invasive or of ecological risk (http://invasoras.pt/en/in-portugal/). With concern to *Robinia pseudoacacia*, the Decree-Law No. 205/2003, of 12 September, transposes into national law the Council Directive 1999/105/EC of December 22, on the marketing of forest reproductive material, and partially repeals the provisions of Article 8 paragraph 2 of Decree-Law No. 565/99, of 21 December, in that it establishes the prohibition of transfer, purchase, sale, offering for sale and transport of live specimens, as well as the production for trade of the same species. However, *Robinia pseudoacacia* continues to be banned for use in Portugal.

The **Swiss** "Ordinance on the Handling of Organisms in the Environment (Release Ordinance, RO)" is the legal basis for the handling of organisms in the environment (CC 814.911 - https://www.admin.ch/opc/en/classified-compilation/20062651/index.html). Invasive alien organisms, in accordance with Annex 2 of this ordinance, may not be handled directly in the environment, other than in the case of measures to control them. Other important references are the Law for the protection of the Environment (LPAmb, RS 814.01, 7 October 1983) and the Federal Law on the protection of Nature and Landscape (LPN, RS 451, 1st July 1966). The Swiss Forest Act on Forest (ForA, RS 821.0) regulates the forests and forestry activities. *The federal ordinance on forestry reproduction material (RS 921.552.1) lists and regulates forest tree species, including a number of alien species allowed under certain circumstances in forestry activities. The federal Plant protection ordinance, OPV, RS 916.20 regulates pests.

The panel of experts on invasive alien plants (European and Mediterranean Plant Protection Organisation, **EPPO**) has established lists of Invasive Alien Plants (EPPO A1/A2 list, List of invasive alien plants, Observation List and Alert list)[135] on the basis of transparent criteria and using the EPPO Prioritization Process on Invasive Alien Plants. EPPO recommends countries endangered by these species to consider measures to prevent their introduction and spread or to manage unwanted populations.

The **German-Austrian** Black List Information System (GABLIS) has been developed as a generic risk assessment tool for invasive alien species in Germany and Austria, and is applicable to all groups of organisms. These assessments are not legally binding. The methodology has so far been tested for fish, vascular plants (including *Acer negundo*, *Ailanthus altissima*, *Fraxinus pennsylvanica*, *Paulownia tomentosa*, *Pinus nigra*, *P. strobus*, *Populus canadensis*, *Prunus laurocerasus*, *Prunus serotina*, *Pseudotsuga menziesii*, *Quercus rubra*, *Robinia pseudoacacia*), mammals, birds and macrozoobenthic species (Essl et al. 2011).

The Non-native Species Secretariat has responsibility for helping to coordinate the approach to invasive non-native species in **Great Britain**. Risk assessments are available for *Eucalyptus glaucescens* (low risk), *E. gunnii* (low risk), *E. nitens* (low risk) (http://www.nonnativespecies.org/index.cfm?sectionid=51).

In **Poland** the use of *Ailanthus altissima* is banned, and could be permitted only by the General Directorate for Environment as stated in legislation (Dz.U. 2011 nr 210 poz. 1260)136.

[135] https://www.eppo.int/INVASIVE_PLANTS/ias_lists.htm

[136] Rozporządzenie Ministra Środowiska z dnia 9 września 2011 r. w sprawie listy roślin i zwierząt gatunków obcych, które w przypadku uwolnienia do środowiska przyrodniczego mogą zagrozić gatunkom rodzimym lub siedliskom przyrodniczym (http://isap.sejm.gov.pl/DetailsServlet?id=WDU20112101260). See also Tokarska-Guzik

In **Slovakia** national legislation addresses the invasive alien species issue, e.g. in the Act No. 543/2002 Coll. on Nature and Landscape Protection as amended[137]. According to its provisions, it is prohibited to import, possess, grow, reproduce and trade invasive species and parts or products originating from them that could cause spontaneous dissemination of the invasive species. Moreover, land owners and land managers are obliged to eliminate invasive species from their land. According to the Order of the Ministry of Environment of SR no. 24/2003 Coll,[138], Annex 2a, these provisions apply only to selected (the most problematic) invasive species. Two tree species, i.e. *Acer negundo* and *Ailanthus altissima* and two shrub species, i.e. *Amorpha fruticosa* and *Lycium barbarum* are listed. Information on invasive allien species (in Slovak language) is available at: http://www.sopsr.sk/publikacie/invazne/index.php. In addition the national legislation in Slovakia provides for regulation of "alien species" (e.g. non-native species not listed as the invasive ones). For instance according to § 7b of the above mentioned Act No 543/2002 Coll. only those wood alien species may be planted outside of built areas of villages - without permission of the competent state body - that are listed in the Annex 1 of the Act No 138/2010 Coll. on Forest Reproduction Material[139]. Planting of other alien wood species outside of built areas of villages requires the permission of the competent state body. This permission is not required within the built areas. The Act No 138/2010 Coll. also specifies reforestation that is allowed again only by species listed in the Annex 1 of the Act.

In **Spain**, the Real Decreto 630/2013, "de 2 de agosto, por el que se regula el Catálogo español de especies exóticas invasoras" (Act 630/2013, 2nd August, that regulates Spanish Catalogue on Invasive Alien Species - http://www.boe.es/boe/dias/2013/08/03/pdfs/BOE-A-2013-8565.pdf) lists *Acacia dealbata, Acacia farnesiana, Acacia salicina, Ailanthus altissima*.

The **Swedish** forest legislation allows for regulations on the use of forest reproductive material in the establishment of new forest stands if warranted from a silvicultural point of view. Consequently, forest material from outside of the EU may not be introduced in Sweden without permit (Petterson et al. 2016). In addition, "foreign" tree species may only be used as forest reproductive material in exceptional cases, although it is generally

allowed to grow the *Pinus contorta* in certain parts of the country (Regulations from the Swedish Forest Agency, SKSFS 1993:2; SKSFS 2010:2.).

Black lists of invasive alien trees (which are not legally binding) have been published in many other countries, e.g. in **Romania** (Anastasiu & Negrean 2005).

Additional and updated information may be found either from national plant protection organisations (that is, Ministries of Agriculture[140]) or from Ministries of Environment in individual countries.

et al. (2012); Woziwoda et al. (2014).

[137] https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2002/543/20150101

[138] https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2003/24/20150101

[139] https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2010/138/20140701

[140] Not in all the Countries. For example, the National Plant Protection Organization of the Netherlands was established in 1899. In 2012 the NPPO merged with other governmental organizations and formed the Netherlands Food and Consumer Product Safety Authority (NVWA). The NVWA is an integral part of the Ministry of Economic Affairs and its head office is based in Utrecht (https://www.nvwa.nl/onderwerpen/english/dossier/national-plant-protection-organization-nppo).