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CODE OF CONDUCT ON PLANTATION FORESTRY AND INVASIVE ALIEN TREES

- SECOND DRAFT -

Document prepared by
Mr Giuseppe Brundu & Mr David M. Richardson
(Department of Agriculture, University of Sassari, Italy - Centre for Invasion Biology, Department of Botany & Zoology, Stellenbosch University, South Africa)
on behalf of the Bern Convention

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(Department of Agriculture, University of Sassari, Italy - Centre for Invasion Biology, Department of Botany & Zoology, Stellenbosch University, South Africa)

Summary

1. INTRODUCTION

Planted forests[1] comprise trees established through planting and/or through deliberate seeding of native or alien (non-native, exotic, introduced[2]) species. Establishment is either through afforestation on land previously not classified as forest, or by reforestation of land classified as forest, for instance after a fire or a storm or following clearfelling. In 2010 total area of planted forest 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)[3].

Afforestation and reforestation have a long history in the northern hemisphere, but it was only in the twentieth century that many tree species began to be planted over large areas in environments far removed from their natural ranges (Richardson 2011). A small number of tree species now form the foundation of commercial forestry enterprises in many parts of the world. Hundreds of other tree species are widely planted for many purposes, including prevention of erosion and drift sand control, for the supply of fuelwood and other products, for ornamentation, and in various forms of agroforestry. In the tropics and subtropics, the bulk of alien tree plantings date from the second half of the twentieth century (Richardson 2011). Agroforestry involves the integration of trees and shrubs with crops or animals on the same land management unit, either in a spatial mixture or in a temporal sequence, to derive the combined benefits of all components. This use of trees has a long history, stretching back to at least the Middle Ages, but until fairly recently native trees were utilized. The widespread availability of thousands of species of non-native trees in the last century or so has revolutionized commercial forestry, agroforestry and arboriculture in general. This has brought major benefits in diverse ways to many parts of the world, but problems caused by invasive alien trees have increased rapidly in the past few decades (Richardson 1998a, 2011).

Non-native trees planted for production 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, non-native trees now feature prominently on the lists of invasive alien plants, and in some areas, non-native woody species are now among the most conspicuous, damaging and, in some cases, best-studied invasive 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[4] (Richardson & Rejmánek 2011), and many tree and shrubs are black-listed in Europe (see Annex 6.2).

Different forms of forestry have provided very important pathways for the introduction and dissemination of alien trees (Wilson et al. 2009; Richardson & Rejmánek 2011; Donaldson et 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 weedy 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

[1] For the purposes of the present Code planted forest and forest plantations are considered equivalent terms. The Code focuses on a subcategory of forest plantations, i.e. on those composed by planted/seeded/vegetatively propagated non-native invasive trees (see also Savill et al. 1997).
[2] The terms alien, non-native, exotic and introduced are considered equivalent for the purposes of this Code.
[3] 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).
[4] http://www.europe-aliens.org/speciesTheWorst.do.

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 plantings (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.

2. PLANTATION FORESTRY

2.1 Global importance of plantations with alien trees

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. 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. 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”[5] (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 rubberwood, 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] 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.

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.

2.2 Alien tree species in Plantation Forestry

2.2.1 General aspects

In the 2010 FAO Global Forest Resources Assessments (FAO 2010a) countries reported on the use of non-native tree species in the establishment of planted forests. Globally, of the 233 countries and areas included, only 117[6] 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, non-native 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 alien 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 species, with 88%, 75% and 65% of plantings comprising introduced species respectively. 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 species Payn et al. (2015).

In eastern and southern Africa, most planted forests consist of non-native 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 (New Zealand) and in South America (Argentina, Bolivia, Brazil, Chile, Ecuador and Uruguay) also comprise introduced taxa. 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.[7]. South America is encouraging the use of intensively managed short-rotation alien species such as *Eucalyptus* spp., *Pinus radiata*, *P. taeda*, *P. elliottii* and *Tectona grandis*.

In East Asia, China uses introduced species on 28 % of the planted forest area while Japan did not report the proportion of non-native 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 species (Indonesia, Malaysia and Vietnam[8]). 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 *Eucalyptus* plantations (Harwood & Nambiar 2014).

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

[7] *Cupressus macrocarpa*, *C. lusitanica*, and the closely related *C. benthamii*.

[8] 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.

In western and central Asian countries (e.g., Turkey[9] - 59,000 ha, FAO 2015a) the use of introduced species is very low, while other countries in this subregion did not report on introduced species. In the temperate and boreal regions of Europe and North America and in the arid zone countries of northern Africa introduced 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 plantation forestry, and foresters rely largely upon non-native tree species. These 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 has 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[10], introduced tree species are reported to occur also on other wooded land (Forest Europe, UNECE and FAO 2011).

The most important alien tree taxa 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 specialized 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 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 and Norgren (1993) have demonstrated that *Pinus contorta*[11] (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 taxa, 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[12], and is now the most economically-important alien tree species in European forests (Schmid et al. 2014). It was introduced to Sweden in the 1920s, and plantations 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 naturalization 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 naturalization of *Pseudotsuga menziesii* in lowland northeastern Austria, and there are naturalized occurrences in most other Central European countries.

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

[9] 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).
[10] 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).
[11] *Pinus contorta* Dougl. var. *latifolia* Engelm.
[12] David Douglas introduced *Pseudotsuga menziesii* to Great Britain in 1827 (Gellini & Grossoni 1996).

consistent success of red oak regeneration in Europe (Riepšas & Straigitė 2008; Kuehne et al. 2014; Woziwoda et al. 2014).

Robinia pseudoacacia stands occupy 20 % (about 400,000 ha) of the Hungarian forest area (Rédei 2002; Rédei et al. 2011b), and it is invading a range of high nature value habitats in continental temperate Central Europe (Kleinbauer et al. 2010)[13]. 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.

Sitka spruce (*Picea sitchensis*) from North America is the most common tree in Great Britain (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 and large shrubs (Peterken 2001). The most commonly introduced 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*. A much more impressive tree is *Quercus* × *pseudosuber* (Lucombe Oak) which was created in a garden in 1762 as a hybrid between two introduced oaks *Q. cerris* and *Q. suber* (Elwes & Henry 1910; Peterken 2001).

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).

2.2.2 Conifers

Many conifers are very widely used in alien forestry, 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[14].

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. 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 other alien 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 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

[13] 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).
[14] See also: Carrillo-Gavilán and Vilà (2010).

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 plantation forestry, non-native 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).

2.2.3 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 forestry trees in the world. Besides pines, eucalypts are the most commonly and widely cultivated alien trees. Over 70 species are naturalized (reproduce and maintain their populations) outside their native ranges. However, given the extent of their cultivation, eucalypts are markedly less invasive than many other widely cultivated 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 (Rejmánek & Richardson 2013), but only two species have been recorded as invasive in Europe (*E. camaldulensis* and *E. globulus*).

2.2.4 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). Introduced 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 plants (Richardson & Rejmánek 2011). Others are only moderately weedy, 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 naturalized 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[15]. *Acacia dealbata* has become a serious environmental problem in

[15] *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).

Northwest Spain, where its expansion is assumed to reduce populations of native species and threaten local plant biodiversity (Lorenzo et al. 2010, 2011).

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).

A total of 33 species in the genus *Acacia* (sensu lato) are listed in the global database of invasive trees and shrubs (Rejmánek & Richardson 2013); 9 species are known to be invasive in Europe (8 taxa from Australia and one from Africa)[16].

2.2.5 Populus and Salix

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[17]) 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[18]).

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 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).

[16] See also Pasta et al. (2012) for the Mediterranean region.
[17] 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/).
[18] http://www.fao.org/forestry/ipc/69994/en/

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).

2.3 Specialised forms of plantations

Apart from traditional[19] types of plantations, alien tree species have been introduced and used for various and multiple reasons, such as gardening, protective functions, arboreta, erosion protection and for increasing the forest area through afforestation of abandoned or derelict land. *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). *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*[20] are both ranked third and are reported as invasive alien trees in several European countries (Forest Europe, UNECE and FAO 2011).

2.3.1 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 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 non-native plants remains an acceptable option for mineland revegetation (D'Antonio & Meyerson 2002; Li 2006) if they fulfil a temporary successional role to colonize and ameliorate severely degraded sites and facilitate colonization and eventual dominance by native flora (Seo et al. 2008).

[19] The terms "specialied" and "traditional" forms of plantations (with alien trees) are used according to Savill et al. (1997).

[20] *Prunus serotina* (syn. *Padus serotina*), a forest tree of North American origin, 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). Between 1900 and 1930, black cherry was planted for multiple uses such as wind and firebreaks, to improve y 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 and, eventually, a species we have to live with. All these perceived qualities served as motives for action by humans without seeking scientific evidence for them: millions of specimens of *P. serotina* were planted. Later millions of Euros were spent in attempts at control. 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 non-native tree species (Starfinger et al. 2003).

2.3.2 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.[21] in Portugal (Knapic et al. 2014), in UK[22] (Evans 1980; Leslie et al. 2012) and in China[23] (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[24] 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".

[21] *E. botryoides, E. camaldulensis, E. cypellocarpa, E. globulus, E. grandis, E. maculata, E. melliodora, E. nitens, E. ovata, E. polyanthemos, E. propinqua, E. regnans, E. resinifera, E. robusta, E. rudis, E. saligna, E. sideroxylon, E. tereticornis* and *E. viminalis*.

[22] 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).

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

[24] 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.

2.3.3 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. When designed and implemented correctly, agroforestry combines the best practices of arboriculture and agricultural systems resulting in more sustainable use of land. Agroforestry is practiced in both tropical and temperate regions, producing food and fibre for improved food and nutritional security. It also sustains livelihoods, alleviates poverty and promotes productive, resilient agricultural environments. In addition, when practiced at scale, it can enhance ecosystems through carbon storage, prevention of deforestation, biodiversity conservation, cleaner water and erosion control, while enabling agricultural lands to withstand events such as floods, drought and climate change.

The potential of agroforestry to contribute to sustainable development has been recognized 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 practices are major features of the land-use systems in the drylands of Eastern and Central Africa. Trees are used for a variety of purposes in both cropped lands and in livestock grazing systems. Trees in the land and homestead find various domestic and commercial applications for both wood and non-wood products (Jama & Zeila 2005).

Agroforestry (or silvoarable agroforestry) consisting of widely spaced trees inter cropped with annual or perennial crops, has traditionally formed important elements of European and Mediterranean landscapes[25], and have the potential to make a positive contribution towards sustainable agriculture in Europe in the future (Eichhorn et al. 2006) and it is supported by the CAP[26].

Nevertheless, many agroforestry systems, particularly those that relay on tree planting in or near treeless landscapes, rely heavily on alien plant taxa[27]. 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 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).

2.3.4 Mediterranean plantations and sand dune stabilisation

Plantations in the Mediterranean have a long history. In mountainous areas, coniferous plantations 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 plantations (e.g., *Pinus nigra s.l.*) or through naturalisation processes. *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

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[25] See den Herder et al. (2015) Preliminary stratification and quantification of agroforestry in Europe. Milestone Report 1.1 for EU FP7 AGFORWARD Research Project (613520). AGFORWARD has defined agroforestry as "the practice of deliberately integrating woody vegetation (trees or shrubs) with crop and/or livestock production systems to benefit from the resulting ecological and economic interactions". This is similar to definitions adopted by the World Agroforestry Centre (ICRAF), the European Agroforestry Federation (EURAF), and the Association for Temperate Agroforestry (AFTA).

[26] Common Agricultural Policy. The regulation on support for rural development by the European Agricultural Fund for Rural Development. (EAFRD), i.e. Regulation (EU) No. 1305/2013, provides measures supporting forestry investment in developing forest areas and improving the viability of forests (afforestation; creation of agroforestry systems); restoration of forests damaged by fires, natural catastrophes and other catastrophic events, and prevention of said damage; improved resilience and environmental value of forest ecosystems; investment in forestry technologies and processing; mobilisation and marketing of forest products, as well as forestry, environmental and climate control services and forest conservation. Provision has also been made for other measures not specific to forestry (Natura 2000 and Water Framework Directive payments).

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

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 plantations dominated by pines (*Pinus halepensis*, *P. pinaster*, *P. pinea*) are very common[28] and are increasing in extent, despite an increase in major forest fires. Traditional forest activities (e.g., cork extraction, maritime pine sawmills) have been replaced by multiple uses linked to tourism, hunting, and recreational activities (Etienne 2000).

In Turkey, afforestation of maritime pine 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 stabilizing 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 2.3.4.1: Colonization 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 clearly beyond the natural distribution of *P. halepensis* as currently recognized (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).

2.3.5 Arid zone plantations: 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. Contrary to popular perception, desertification is not the loss of land to the desert or through sand-dune movement. 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).

[28] *Cfr* 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).

Sand encroachment[29], 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*[30] 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).

2.3.6 Genetically improved and genetically modified alien trees

Diverse biotechnological methods are being intensively pursued to support plantation forestry with alien trees. These include clonal propagation[31], interspecific hybridization, 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[32], 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

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[29] 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).

[30] 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).

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

[32] 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).

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[33], 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 plantations (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 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 hybridization, 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 plantations 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 recognized 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

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[33] *Cfr*, Ledford (2014).

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.

2.4 Benefits arising from plantation forestry with 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).

Alien trees can simultaneously bring many 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 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).

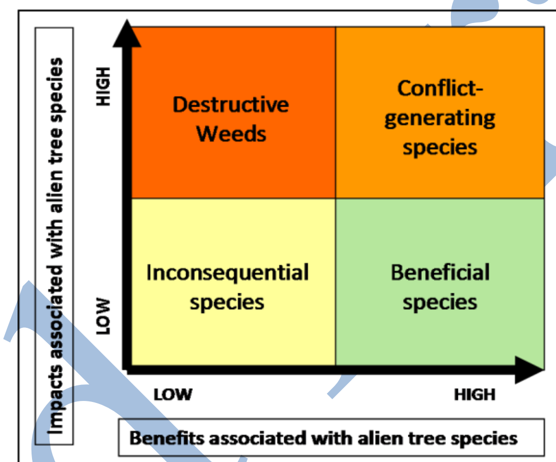

Fig. 1 – Types of invasive alien trees based on their relative degree of impact on the environment and the benefits associated with their cultivation and utilization. Redrawn from van Wilgen & Richardson (2014). The position of any alien tree species within this framework is dynamic.

According to the categorization proposed by van Wilgen & Richardson (2014), many introduced 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 stabilization 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 categorization 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 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 benefits of alien trees that are both useful and invasive arise largely from two sources, timber production and aesthetic value and appeal. Other benefits include: 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 can reduce pressures on indigenous forest for forest products and allow them to be designated for other protective and conservation purposes (FAO 2010c; Mead 2013).

The role of alien tree plantations in biodiversity conservation is contested (Brockerhoff et al. 2008). For example, in the fragmented forest landscape of Europe, tree plantations comprise an increasingly important fraction of the matrix surrounding natural forest fragments. Plantations 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 *Eucalyptus* globulus plantations in Galicia, Spain, compared with the diverse and abundant avifauna in pine plantations. 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 plantations, by limiting the presence of phytophagous insects and thus the availability of prey for birds (Calviño-Cancela 2013).

2.5 The negative impacts of invasive alien trees

2.5.1 Generalities and key examples

The pathways created by the use of non-native trees in commercial forestry and agroforestry have resulted in many serious problems with invasions. Invasive alien trees have affected 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 *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[34] has changed large areas of open grassy marshes to closed-canopy swamp-forests.

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[34] *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

The net effect of invasive non-native 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 trees have no obvious impacts, some have localized 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 summarized 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 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.[35] 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 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 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 tree invasions result in reduced horizontal continuity of fuel which reduces fire frequency and intensity (Brooks et al. 2004).

Sand stabilizers: Australian *Acacia* species have been widely planted along coastal dunes in several parts of the world to stabilize sand movement. Planted and self-sown stands of species like *A. cyclops* perform this function very well; in some areas of South Africa dune stabilization has resulted in massive beach erosion. In the Portuguese dune ecosystems, *Acacia longifolia* and *A. saligna* are among the most aggressive invasive plant 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. 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 pro-longed drought periods predicted to occur in Portugal in the future (Rascher et al. 2011).

Colonisers of intertidal mudflats/sediment stabilizers: Red mangrove (*Rhizophora mangle*) was introduced to Hawai'i in 1902 to control runoff from upstream agriculture. Other species of 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,

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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).

[35] 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 woody riparian taxon in the western United States (Friedman et al. 2005).

sediment stabilization, 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, 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. Introduced 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 plantations 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 invader (Pyšek & Prach 2003). In Central Europe, many sandstone areas are protected for their unique environment, and large-scale regeneration of this alien tree species is of concern (Hadincová et al. 2007; Mandák et al. 2013).

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[36] in number compared to planted individuals of the introduced 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 tree and shrub invasions affect resident biota in more subtle ways. An important category of impacts for invasive woody plants 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 woody plants can cause. In Hawaii, the spread of introduced 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 colonized by various introduced barnacles and sponges, thus altering the structure of macrofaunal communities. Many species have a major impact by creating impenetrable thorny thickets that limit the passage of animals (e.g., *Caesalpinia decapetala*, *Mimosa 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 *Pittosporum undulatum* and other 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), 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

[36] 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).

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). Tree invasions have huge financial costs in many regions.

In Britain several introduced 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) recognized the analogy between invasion of *Cinchona pubescens* into shrubby highland communities of the Santa Cruz Island, Galapagos, and invasion of pines and acacias into fynbos shrublands in South Africa. These 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 forestry purposes, 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 invasive primarily in these types of habitats where is expected to spread further (Gederaas et al. 2012).

Box 2.5.1.1 Invasive Acacia species.

Invasive *Acacia* species, like many other invasive species, have many types of impacts including some that interact synergistically. *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 Australian acacias on biodiversity and ecosystem properties and functions also affect the delivery of ecosystem services and the benefits that society derives from them. 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 forest plantations 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).

2.6 International initiatives and legislation

Many international instruments refer to 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 plantation forestry. The information here provided is intended to provide support to the principle 4.1.1 of the present Code.

2.6.1 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 alien tree species. In particular, the COP 11 Decision XI/19[37] 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) Prioritizing, 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".

2.6.2 The Council of Europe and the Bern Convention

The Council of Europe[38] 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[39]".

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

[37] 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". *Cfr* 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.

[38] 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).

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

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[40].

2.6.3 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), recognized 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 (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).

2.6.4 The European and Mediterranean Plant Protection Organisation (EPPO)

The European and Mediterranean Plant Protection Organization (EPPO) is an intergovernmental organization 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 an 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 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[41].

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[40] 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. 160 (2012) of the Standing Committee, adopted on 30 November 2012, on the European Code of Conduct for Botanic Gardens on Invasive Alien Species.

[41] 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).

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

2.6.5 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. It has three different levels of protection for species, reported as Appendices[42]. Although there are literally thousands of plant species protected under 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*[43] and *Dalbergia nigra*[44] are included in Appendix I. 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).

2.6.6 Sustainable forest management and forest certification

Standards, guidelines, criteria and indicators for sustainable forest management (SFM) have been developed over the past few decades by intergovernmental processes, international organizations[45], and certification schemes (e.g. FSC, PEFC) (Masiero et al. 2015). Most activity began 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 forestry practices and the 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 have adopted in 2003 a set of criteria and indicators and are continuously adapting them due to new challenges[46]. Also the International Tropical Timber Organisation ITTO has developed and is revising criteria and indicators for sustainable forest management since the early 1990's[47]. The majority of

[42] 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 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.

[43] *Araucaria araucana* has been widely planted as a specimen tree in temperate areas all over the world, but there are virtually no plantations. 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).

[44] *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).

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

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

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

standards and guidelines are focused on natural or semi-natural forests while planted forests and forest plantations with native or alien tree species are considered only marginally (Masiero et al. 2015).

Forest certification is a voluntary conservation 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 organizations, 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[48]) and the Programme for the Endorsement of Forest Certification (PEFC[49]). FSC is a global forest certification scheme. PEFC is an umbrella organization that endorses national schemes, some of which were developed 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[50] 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 Organization[51] shall only use alien species[52] when knowledge and/or experience have shown that any invasive impacts can be controlled and effective mitigation measures are in place”.

The primary institutional response to the FSC’s growing influence was the establishment of competing forest certification programs such as the US Sustainable Forestry Initiative (SFI) and the Pan European Forest Certification Council (PEFC). Promoted primarily by landowner and industry-based groups, many of the new programs were designed to legitimate existing practices (Meidinger 2011).

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[48] 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) theSC 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.

[49] 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).

[50] 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].

[51] 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).

[52] 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.

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.

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.

The forestry industry often perceives FSC standards as being incompatible with plantation forestry. One of the ten FSC principles (Principle 10) addresses plantations directly, which it defines as “intensively managed treed areas with few natural characteristics. They exist for timber production purposes and are not managed to provide other values or amenities on the planted sites”.

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)[53].

The international FSC standard states that native species are preferred, but alien species are tolerated as long as their use is monitored and carefully controlled, and adverse ecological effects are avoided (Criterion 6.9). Natural 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[54] 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[55]), or that they only be used in plantations or plant nurseries, or if needed to maintain historical places (FSC Russia)[56] (Stupak et al. 2011).

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[53] Cfr 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 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.

[54] (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

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

[56] 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

Native species are also generally preferred by PEFC (see the Pan European Operational Level Guidelines, PEOLG[57]), but the use of alien species is allowed as long as negative impacts can be avoided or minimized.

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[58] draft 2009), and the SFI draft 2009, in agreement with PEOLG, requires the use of aliens to be minimized. 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 recognized scientific methods to track their plantations and follow national regulations as well as other international protocols (Morissette 2012).

2.7 European initiatives and legislation

2.7.1 Habitat Directive – Natura 2000

The Habitats Directive[59] (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 so called "habitat types" (e.g. special types of forests, meadows, wetlands, etc.), which are of European importance. According to Article 22.b, in implementing the provisions of this Directive,

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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 plantation 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 noninvasive 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).

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

[58] Sustainable Forestry Initiative (http://www.sfiprogram.org).

[59] 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].

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 2.7.1 - 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 alien tree species such as *Acacia* spp. and *Cryptomeria japonica* (Hervías Parejo et al. 2014).

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 forest plantations 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 plantations to forests resembling the laurel forests in structure and composition.

Management of Natura 2000 habitats[60] 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.

2.7.2 The Plant Health Regime in the European Union

European Union rules on plant health[61] 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

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

[61] 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.

organisms (pests) within the Community, as a result, the introductions of some tree species might be restricted or specifically regulated due to phytosanitary reasons[62].

2.7.3 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[63].

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.

2.7.4 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[64] 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 minimize and mitigate the human health or economic impacts that these species can have[65].

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.

2.7.5 EU Forestry Policy and CAP

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 sectoral 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

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[62] 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.

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

[64] 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).

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

amenities, biodiversity reservoirs, regulators of climate and local weather, sources of clean water, protection against natural disasters and renewable energy sources[66] (European Commission 2003).

In 1992, the European Commission launched a program to increase afforestation activities on farmland[67]. The purpose of the program was to reduce the costs of agricultural subsidies. Landowners willing to convert agricultural land into forest production 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 program's launch, about a million ha were afforested in the European Community, mainly in Spain, 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[68] (Dohrenbusch & Bolte 2007; Lefebvre et al. 2012).

The EU Forestry Strategy[69] adopted in 1998 puts 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[70].

In 2006 the EU underpinned its support for sustainable forest management and the multifunctional role of forests by adopting an EU Forest Action Plan[71]. The plan was a framework for forest-related

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

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

[68] 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 silvatica), 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).

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

[70] [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 (cfr 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 … ".

[71] 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].

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.

On 20 September 2013 the Commission adopted a new EU Forest Strategy[72] 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, 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).

2.7.6 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 invasive alien trees.

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

3. Code of Conduct

3.1 Audience and aims

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 introductions of invasive alien tree species in Plantation Forestry.

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 also be taken into consideration by private or public gardens or arboreta in Europe with major collections of alien trees that are not considered forest plantations 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 forest plantations of alien trees in Europe and the Mediterranean, many examples and many if not most of the recommendations for action contained in the Code will be of relevance to forest plantations in other countries and regions, as a small number of tree species now form the foundation of commercial forestry enterprises 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.

3.2 A voluntary tool

This Code is voluntary. All stakeholders concerned with the planning, the management and development of Plantation Forestry, 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 publicize 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.

3.3 Implementing, monitoring and evaluating the Code

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 alien trees, and those who perceive, and are affected by, negative impacts of these invasion alien trees.

4. THE PRINCIPLES OF THE CODE

The pathways created by the use of non-native trees in commercial forestry and agroforestry have created many serious problems with invasions worldwide. Invasive alien trees have affected invaded ecosystems in many ways (e.g., Richardson 2011; Richardson & Rejmánek 2011)[73]. Afforestation and reforestation policies, both in public and private land, need to include clearly stated objectives and principles to reduce impacts outside areas set aside for forestry. Containment of alien trees to areas set aside for their cultivation must become an integral part of silviculture (Richardson 2011).

4.1 Awareness

4.1.1 Be aware of regulations concerning invasive alien trees

Those engaged in the plantation forestry sector need to be aware of their obligations under regulations and legislation. The main obligations under existing laws and treaties are detailed in previous sections of this Code (2.6 – 2.7).

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 28 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 plantation forestry 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. Information may be found either from national plant protection organisations (that is, Ministries of Agriculture[74]) or from Ministries of Environment in individual countries.

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)[75], 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 aliens trees within natural woodlands is discouraged (Gunnarsson et al.

[73] *Cfr* Section 2.5 in this Code.
[74] 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).
[75] There is no prohibition against using alien tree species, but according to the Regulation on non-native trees, a permit is required for planting non-native trees. The new Forestry Act and regulations on sustainable forestry is also to some extent used to regulate the maintenance of introduced tree species. In recent years, the National Forest Inventory, a national monitoring programme, has been expanded to include alien tree species and their spread, and various projects have been carried out to gather information on alien tree species in Norway. Some tree species are also included in the national black list (Gederaas et al. 2012).

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[76].

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).

4.1.2 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, and the list is growing as more tree species are moved around the world and become established in novel environments (Rejmánek & Richardson 2013; van Wilgen & Richardson 2014).

The impacts of non-native trees generally increase if the species establish themselves and spread in their new environment outside the area of cultivation (i.e., if they become invasive *sensu* Blackburn et al. 2011), but non-native tree species can have impacts even when they are not fully established or widespread (Ricciardi & Cohen 2007; Jeschke et al. 2013; Jeschke et al. 2014). Indeed, non-native tree species can have impacts as soon as they are introduced; for example, allergic pollen can affect human health, they can act as vectors of new pests or pathogens for other plant 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).

Increasing awareness of problems associated with invasive forestry trees means that information on invasive 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. Ignorance is no longer an excuse for disseminating invasive alien trees (Richardson 2011). Global lists of invasive alien trees are available (Richardson & Rejmánek 2011; Rejmánek & Richardson 2013). "Invasive elsewhere" is one of the most robust predictors of invasiveness. There is strong evidence that species replicate invasive behaviour in environmentally-similar conditions in different parts of the world.

The fact that some alien forestry trees have not yet spread from given planting sites should not be taken as evidence that invasions will not occur in the future. Experience with the same species 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).

Many countries have national or sub-national black lists, identifying those alien species whose introduction is prohibited or discouraged due to their potential adverse effects on the environment or human, animal or plant health. Alien tree species black-listed should not be used for new plantations.

An alternative approach used in other countries relies on the "white list" (or red, green and amber, see Perrings et al. 2005; Simberloff 2006) of low invasion risk alien species, including trees.

Both listing systems have pros and cons (Simberloff 2006). For example, 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 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".

[76] 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/).

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. In some countries these lists are supported by dedicated legislation, in other cases they are not legally binding even if scientifically sound, with priorities based on a rigorous risk assessment process.

For each new alien tree species or provenance[77] introduced which has not already been evaluated, those[78] introducing the species or planning new plantations could run the "pest categorization part" of the EPPO PRA scheme (EPPO Standard PM5/3, 1997) consisting of a few questions. Actually, there are over 100 risk assessment models for invasive plant species (Leung et al. 2012), 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).

According to Křivánek & Pyšek (2006) two main groups of risk assessment models can be recognized, based on the methods used and the phase of the invasion process they target: (1) pre-introduction models predicting the potential behaviour of a species prior to its introduction; (2) post-introduction models predicting the future behaviour of species that have already become naturalized or invasive in the new area. 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.

4.1.3 Develop systems for information sharing and training programmes

The efficacy of any strategy to address invasive alien trees strictly depends on the available information, and on the sharing of data, knowledge and experience[79]. Information sharing systems would greatly improve the ability of authorities to prevent the introduction and spread of invasive tree species.

Additionally, invasive 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, and in the management of both natural forests and non-native tree plantations.

[77] "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).

[78] 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).

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

4.2 Prevention & Containment

Actions aiming at preventing the potential risk posed by invasive alien trees or limiting their spread from plantation sites, 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.

4.2.1 Promote – where possible – the use of native trees

The use of native species or non-invasive alien or less-invasive[80] alien tree species as alternatives for highly invasive alien species in plantation forestry should be always considered[81], as should the precise provenance of seeds and germplasm (Aarrestad et al. 2014).

The practical objections to this obvious principle are well known, as are the most important reasons for using alien trees instead of native trees (Savill et al. 1997; Richardson 1998a; Richardson 2011). For example, alien tree species generally produce more timber than native species and seeds are more readily available. Nevertheless, this principle has clear advantages for the other objectives of forestry (Peterken 1977).

Plantations of non-native species of *Acacia*, *Eucalyptus* and *Pinus* and 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).

[80] For example, Lorentz and Minogue (2015) remark that trait selection during breeding is one potentially very effective containment approach for managing 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 sterile clones of *Pinus* species used in South Africa and triploid hybrid *Leucaena* in Hawaii (Richardson 1998a). 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, imprecise and complex ecological research to understand and predict the impacts of spread (FAO 2010d). However, the major limitation to this approach is that the permanence of containment technology is uncertain due to relatively novel use in forestry (FAO 2010d; Lorentz & Minogue 2015).

[81] FAO Principle 9 "Conservation of biological diversity" states that " … FAO encourages the establishment of planted forest 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).

BOX 4.2.1.1 - Use of native 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 species plantations, where the main objective is timber and pulp production, has led to a neglect of other services 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 plantations has negative impacts on the environment, making it necessary to evaluate alternative tree species for use in commercial forestry. The actual crisis in the forest sector of the region could be an opportunity to change to plantations of native 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 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 debatable.

Rodríguez-Loinaz et al. (2013) showed that substituting existing alien plantations with plantations of native 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 plantations of native species is the greatest. Thus, changing from pine and eucalypts to plantations of native species sequesters more C in the long-term, while solving some of the environmental problems caused by the aliens. 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 aliens (Rodríguez-Loinaz et al. 2013).

BOX 4.2.1.2 – Native riparian woodlands in Ireland and the Native Woodland Scheme (NWS).

In some areas of Ireland, afforestation with coniferous plantations has impacted negatively on native riparian woodlands and the aquatic ecosystem, particularly where planting was carried out up to the water's edge (Hickie 1997; Heritage Council 1999; McGarrigle & Cleneghan 2004). In such cases, excessive shade coupled with siltation during ground preparation and harvesting undoubtedly had negative impacts on the aquatic system. It is also likely that some native riparian woodland fragments were converted to conifer plantations. As a result of all these factors, very few extensive natural riparian woodlands remain in Ireland, and most of those that do remain are fragmented and greatly reduced in area. Introduced in late 2001 by the Forest Service, NWS is a grant package that provides funding to restore existing native woodland and to establish new native woodland on a range of sites, including those adjacent to water bodies such as streams, rivers and lakes. On such sites, the scheme provides a mechanism to address the dual purpose of conserving and expanding native riparian woodland, and protecting and enhancing the adjacent aquatic habitat and water quality. The NWS also encourages appropriate wood production as a secondary objective where compatible with biodiversity, using "close-to-nature continuous cover silvicultural systems" that take into account the sensitivities of the existing habitats and soils (Declan et al. 2014).

BOX 4.2.1.3 - 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 forest plantations 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. With 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 forest plantations, 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 aliens 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 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 aliens might be compromised, since alien 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 aliens 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 and Condit 2001; Wishnie et al. 2007; Garen et al. 2009).

4.2.2 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)[82].

Nurseries can act as important sources of alien species into plantation sites. Many forest pests, both insects and pathogens, have also entered new lands via nursery stock[83].

BOX 4.2.2.1 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,

[82] *Cfr* 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).

[83] 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].

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).

4.2.3 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 (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 forestry trees should be incorporated in such a strategy.

Examples of practices that should be applied in alien tree plantations include the following:

- Research findings should be applied to identify the most appropriate sites for cultivation within landscapes;
- Biodiversity issues must be considered in plantation design (e.g., Carnus et al. 2006; COP 11 Decision XI/19 8 - 19 October 2012 - Hyderabad, India[84]);
- Avoid converting natural habitats for cultivation[85];
- Restrict plantings to areas where alien tree species are already present;
- Limit the total allowable area of planting, 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 or along margins of unplanted reserve areas inside plantations[86];
- Design plantation 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 production forest, wide roads);
- Whenever possible, use mixed-species plantations (Brockerhoff et al. 2008) and encourage structural diversity through different age classes (Evans 2009b);

[84] 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).

[85] 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, in FAO (2006b).

[86] 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.

- Encourage the establishment of representative natural forest within the plantation estate and, where possible, restore natural forests on appropriate sites (Secretariat of the Convention on Biological Diversity 2009);
- Prevent plantings at sites most favourable for long-distance dispersal of seed or pollen (hill tops, ridges);
- Prevent plantings and minimize disturbance near wetlands, rivers and streams and create buffer zones[87];
- Prevent plantings near Natura 2000 sites and other protected areas or endangered habitats;
- Minimize 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 Europe[88], 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 *Eucalyptus*[89].

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 prioritize 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, fertilization, and herbicide applications (Neary 2011). Plantation forestry practices, including clearfelling and thinning, are recognised as a potential source of pollution to receiving waters and are a risk to the ecological status of surface waters[90] (e.g., Drinan et al. 2013). Best management strategies

[87] Type and size of the buffer would depend on the alien tree species used in the plantation. 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).

[88] "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).

[89] 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).

[90] 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).

should therefore be applied for reducing the run-off of plantation forestry-derived nutrients to receiving waters.

The impact of invasive alien conifers on hydrology can be enormous, particularly where they replace non-forest vegetation. In South Africa, invasive introduced 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).

Gene flow is a primary determinant of potential ecological impacts of transgenic tree plantations. 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[91]. Specific containment measures could be applied also at the plantation level[92], both in the case of confined field trials and unconfined releases (Häggman et al. 2013).

Good plantation practices could also limit the spread of pathogens and pests within plantations 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 plantation forest. Finally, good planting practices and restrictions should be always supported by monitoring for wildings and targeted removal programs.

4.2.4 Revise general land management practices in landscapes with planted forests

In many cases, options exist for managing plantations of non-native trees and adjoining areas (invaded or potentially invasible) by manipulating disturbance regimes (e.g., fire cycles, grazing levels) to impede invasion. Improved solutions to problems caused by invasive alien trees lie in better integration of available control methods.

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 plantations 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).

Specific attention and management practices should be followed in the case of genetically modified tree plantations, 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[93] includes aliens as well as transgenics; Bonfils 2006; Meirmans et al. 2010).

[91] 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).

[92] 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.

[93] 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. *Cfr* also the Cartagena Protocol on Biosafety (http://bch.cbd.int/protocol).

Forest plantation 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[94] must be always taken into account when planning the use of prescribed burning in plantation forests. A valuable reference is Fire management: voluntary guidelines. Principles and strategic actions (FAO Fire Management Working Paper No. 17, 2006c)[95], which outlines voluntary guidelines for fire management, including in planted forests.

Finally, tailored management practices should be followed in the case of plantations 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 alien plantations is recommended.

BOX 4.2.4.1 – Management of the North American lodgepole pine in Sweden.

The North American lodgepole pine (*Pinus contorta* var. *latifolia*) was introduced to Sweden in the 1920s on an experimental scale, but from the 1970s onwards large plantations of this species were established; these now cover about 475,000 ha, mainly in the northern area (SLU 2010). The large-scale planting of *P. contorta* had as its main objective to meet the predicted shortage of harvestable softwoods. Large areas were initially planted, but after the 1990s the extent of new planting decreased. Problems such as pathogens and tree instability also contributed to the decrease in new plantings. During a workshop on lodgepole pine ecology in Ammarnäs, Sweden in 1998, participants discussed the implications for long-term sustainability and suggested management measures that, according to existing knowledge, would minimize the deleterious effects of such introductions (Andersson et al. 1999). In particular, the importance of a strategy which takes account of uncertainty was stressed. This would enable the introduction to proceed while the effects of the introduction were continuously examined. One component of such a strategy was to limit the total area planted with lodgepole pine. A second component was to ensure that landscapes free of lodgepole pine would be maintained. A third component was to retain old stands of lodgepole pine. Together, it was argued, these components would facilitate the accumulation of knowledge on the development of this novel ecosystem, and to discover how the native fauna and flora

[94] 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.

[95] 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).

make use of lodgepole pine throughout its potential rotation. Another requirement was for an early-warning system to identify problems before they become widespread. The basic idea was to establish a system for routine observations and a plan which could be activated if a problem arose. The early-warning system included the monitoring of certain groups of native flora and fauna. The most obvious groups would probably be birds and Lepidoptera, which are well known by a large number of naturalists, and may be sensitive to changes in the environment. A system which included non-professional observers would maximise the level of surveillance and generate wider support for the monitoring program. The basic need would be for a standard method of recording and a central coordinator for collecting and analysing the observations. The coordinator could also be identified as a contact point for any individual who notices a possible problem attributable to lodgepole pine. There would also be a plan of action in the event of a particular problem (Engelmark 2001). Nevertheless, this strategy was not fully implemented in Sweden, and the main problem today is how to control the spread of *Pinus contorta* var. *latifolia*. There are also negative effects of lodgepole pine on the livelihoods of indigenous peoples (reindeer herders) due to the effect on decreasing lichens abundance (Korosuo et al. 2014).

4.2.5 Adopt good practices for harvesting and transport of timber

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[96].

Harvesting[97] and transport of non-native trees should be planned, supervised and undertaken by appropriately trained personnel. Good practices should minimise the risk of further spread of invasive alien species, and the disturbance that could promote the establishment of other invaders. Careful planning will substantially reduce the road density[98] required within a 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. Wash machinery where weed transfer is an identified risk.

Forest personnel should be trained to recognize and report unusual pests and symptoms of diseased or infested trees, and to carry out practices that reduce the risk of pest and weeds populations moving to other locations[99]. Personnel should wear outer layers of clothing and footwear that are not "seed friendly" (*sensu* USDA 2012) to minise the risk of spreading alien species accidentally.

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[96] The North American *Elodea canadensis* was first observed in Europe in 1836, in an Irish pond. Marshall (1852, 1857) supposed that the plant had been introduced, probably from America, and suggested that either it had been deliberately introduced, or had been carried over on American timber which had picked up small pieces of the plant when being rafted downriver after felling.

[97] Harvesting is the end-point of a plantation 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).

[98] 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 plantation 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.

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

4.2.6 Adopt good practices for habitat restoration

It is necessary to adopt specific guidelines for the restoration of sites previously occupied by plantations with 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 alien tree plantations established for lumber production or a variety of other forestry purposes. Not all alien tree plantations develop species-rich understories; some remain as 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 plantations of *Robinia pseudoacacia* have been produced in the Piedmont region of Italy[100]. Sturgess and Atkinson (1993) suggested management strategies for the restoration of near-natural sand-dune habitats following the clearfelling of *Pinus* plantations in Britain, and Brown et al. (2015) proposed approaches for plantations 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 alien pine plantations 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, Canary Islands (Spain). Hughes (2003) and Moss and Monstadt (2008) propose management guidelines for the restoration of floodplain forests[101] in Europe.

4.3 Early Detection & Rapid Response

4.3.1 Promote and implement early detection & rapid response programmes

Early detection and initiation of management can make the difference between being able to employ feasible offensive strategies (eradication) 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 tree invaders can also enable more rapid reaction (Richardson 2011; Faulkner et al. 2014).

The relatively long initial lag phase between introduction and naturalization/invasion and slow dynamics observed in many forest plantation 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 invasiveness reported inside the forest plantation or in its proximity should be carefully monitored so as to avoid serious problems developing. If the forest plantation includes an area of native

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

[101] Very few floodplain forests remain in Europe. y per cent 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 s. 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 forestry plantations(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).

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[102] 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 forest plantation (Froude 2011).

However, experience with introduced 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/ 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). Widespread natural establishment of *E. globulus* plants in Portugal was recently documented by Águas et al. (2014) and Catry et al. (2015).

Natural regeneration of alien conifers is considered desirable in some instances. For example, changing forest policy in Great Britain requires “lower impact silvicultural systems” 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 naturalization and invasion, is thus a highly topical issue (Richardson & Rejmánek 2004).

4.3.2 Establish or join a network of sentinel sites

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 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 plantations 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. Plantations of alien trees have been a major source of tree invasions (Richardson & Rejmánek 2011; Dodet & Collet 2012), and should form part of any sentinel site network for monitoring alien tree invasions. Other areas that are likely to act as sources of propagules and sites of entry for new invasions

[102] “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).

are areas of human habitation where gardens have been established (Alston & Richardson 2006), and experimental plantings, arboreta or botanical gardens containing alien tree species.

Visser et al. (2014) have shown that Google Earth can be an useful tool for establishing a global sentinel site network for 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 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).

4.4 Outreach

4.4.1 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 (e.g., Hemström et al. 2014)[103]. The active and informed participation of communities and stakeholders affected by plantation 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[104], 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.

[103] 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).

[104] 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).

Forestry has become more complex over the years. This form of landuse now impacts on 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.

4.5 Forward Planning

4.5.1 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 plantations of alien trees are good places to conduct research on topics such as the spread, control, management and risks posed by invasive alien trees in collaboration with national or local environment agencies, research centres and appropriate regional or European bodies[105].

Great Britain, for instance, with its long history of tree introductions and large plantings of many alien species (e.g. *Picea sitchensis*, the commonest British tree; Peterken 2001), is a good natural laboratory for studies of the determinants of naturalization 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).

4.5.2 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 worldwide (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).

For example, global change, with rapidly changing climate patterns, altered disturbance and nutrient regimes, and increased fragmentation are very likely to favour considerable expansion of pine invasions worldwide (e.g., Higgins & Richardson 1999; Richardson & Rejmánek 2004).

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[105] 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].

Bernier and Schoene (2009) propose three possible approaches for adapting forests to climate change: no intervention, reactive adaptation and planned adaptation. Unfortunately, most current management belongs to the first or at best to the second category.

No intervention means business as usual, with tree species selection, management targets and practices based on the premise that the 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.

In plantation forestry, climate change could affect the dynamics of alien 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 always choosing native species (UK Forestry Commission[106]). Also assisted migration[107] 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).

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

Finally, it is very important to incorporate climate change into risk models for an anticipatory evaluation of scenarios for invasiveness of alien trees. Risk maps[108] 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. For example, Kleinbauer et al. (2010) suggest that the area suitable for invasions by *R. 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 species under future climates. On the contrary, González-Muñoz et al. (2014) did not predict an enhancement of *A. 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.

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[106] 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)..

[107] 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).

[108] 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).

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6. ANNEXES

6.1 Definitions – Glossary

The terminology used in legislation and in the literature when discussing alien and invasive species can be complex and confusing as many of the terms have been used in different ways by different authors. Unless referenced, definitions follow Richardson et al. (2011), Blackburn et al. (2011), Jeschke et al. (2014) and Code of Conduct on Horticulture and Invasive Alien Plants (Heywood & Brunel 2009, 2011) and 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). The terms alien, non-native, exotic and introduced are considered equivalent for the purposes of this Code.

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 nonforest 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[109] 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

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

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).

Forest Plantation

In FRA 2000 "forest plantations" were defined as those forest stands established by planting or/and seeding in the process of afforestation or reforestation. They are either of introduced or indigenous species which meet 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. 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 rubberwood, cork oak and Christmas tree plantations (Payn et al. 2015). For the purposes of the present Code planted forest and forest plantations are considered equivalent terms. The Code focuses on a subcategory of forest plantations, i.e. on those composed by planted/seeded/vegetatively propagated non-native invasive trees (see also Savill et al. 1997).

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).

Impact

The description or quantification of how an alien species affects the physical, chemical and biological environment.

Invasion debt

A concept that posits that even if introductions cease (and/or other drivers of invasion are relaxed, e.g., propagule pressure is reduced), new invasions will continue to emerge and already-invasive species will continue to spread and cause potentially greater impacts, since large numbers of alien species are already present, many of them in a lag phase. (Essl et al. 2010). Many species currently used in forestry are not yet invasive in all regions where they have been planted. The invasion debt in such areas needs to be considered in long-term planning.

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.

Invasiveness

The features of 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.

Sustainable forest management

The term "sustainable forest management" can be traced to the non-binding 'Forest Principles' and Chapter 11 of Agenda 21, which were prominent outputs of the United Nations Conference on Environment and Development (UNCED) in June 1992.

Despite, or perhaps because of, the long maturation process of the sustainable forest management concept, it is difficult to explicitly define sustainable forest management (FRA 2010). According to the Joint Pan-European Definition of Sustainable Forest Management: "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 (FOREST EUROPE, UNECE and FAO 2011).

Transformer invasive alien species

A subset of invasive plants which change the character, condition, form or nature of ecosystems over a substantial area relative to the extent of that ecosystem (Richardson et al. 2000).

6.2 The most frequently listed 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 nordmanniana									
Abies pinsapo									
Abies procera						LO			
Abies sibirica						PH			
Acacia cyanophylla							Annex I		
Acacia cyclops					MPI				
Acacia dealbata				Potential			Annex I	Watch-List	Invasive
Acacia decurrens									
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	
Salix viminalis				Uncertain	PH			
Thuja plicata					LO			

Table 1 - The fifty alien trees most frequently listed (with different rankings) in different European countries (DK = Denmaerk, BL = Belgium, IT = Italy, IR = Ireland, NW = Norway, PT = Portugal, SW = Sweden, EPPO = EPPO Region). The table includes both tree species alien "to" and alien "in" Europe or in the EPPO region. Plants names are reported exactly as they are found in the original source, regardless of synonyms (e.g. Acacia cyanophylla Lindl. is a synonym for Acacia saligna (Labill.) Wendl.).

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**[110] 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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[110] 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** "Ordonnance sur la dissémination des organismes dans l'environnement" 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). 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**, https://www.eppo.int/INVASIVE_PLANTS/ias_lists.htm) has established lists of Invasive Alien Plants (EPPO A1/A2 list, List of invasive alien plants, Observation List and Alert list) 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 assessment 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)[111].

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*.

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. 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,, 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.

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

[111] 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 et al. (2012); Woziwoda et al. (2014).